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Technical Report

No. 13297

SIMULATION TEST OF THE MK19 MOD3 GRENADE

MACHINE GUN SUPPORT KIT

OCTOBER 1987

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A new prototype MK19 MOD3 Grenade Machine Gun Support Kit was designed and developed for the M342A2 (w/w) 2½-ton truck. This report details a unique test that was implemented in TACOM's Physical Simulation Laboratory to reproduce the dynamic forces the machine gun kit normally encounters as the truck travels across terrain. The truck was simulated over selected terrains which produced the state variables of the fixture. Real-time simulation testing of prototype vehicle systems is a proven method of reducing costly development and field time testing.

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PREFACE

I would like to thank the staff of the Systems Simulation and Technology Division for the following contributions: Mr. Borg, for design of the hydraulic actuators/suspension test fixtures for the truck, design support to the hydraulics, and supervision of the preparation of the truck for laboratory simulation; Mr. Hudas, for instrumentation and computer interface; Mr. Reid, for computer programming support including the development of plot and data logging routines for truck data; Mr. Rohweder, for Dynamic Analysis and Design of Systems (DADS) complete analytical simulations; Mr. Haley, for technical guidance and analytical simulation support; and, Mr. Zywiol, for technical guidance, preparation of the hydraulic controllers for the simulator and computer programming support.

I would also like to thank the people from the Technical Support Division for the following contributions: technician support (hydraulics and electronics); preparation of the test bed; continuous observation of the test; and, maintenance and frequent inspection of the truck. The assistance of Mr. Reininger, chief of the Simulation Branch, was much appreciated.

This project was coordinated by vehicle engineer Doug Petron, of the Light and Medium Truck Branch.

It takes team work to run a test at this level. Everyone's contributions were needed and appreciated.

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1.0. INTRODUCTION

This report, prepared by the Systems Simulation and Technology Division, of the U.S. Army Tank-Automotive Command (TACOM), details a unique test that was implemented in TACOM's Physical Simulation Laboratory to reproduce dynamic forces that a machine gun kit normally encounters as an M342A2 (w/w) 2½-ton truck travels across terrain. The report describes the simulation process, the results of the testing, and some of the data recorded during the simulation testing. The machine gun kit tested is a new version developed to support the MK19 MOD3 machine gun.

The new support kit, developed by AM General, is used on various trucks and consists of a machine gun ring fixture which is mounted to the back and front of the truck cab. The support kit design consists of a slightly modified version of the current model (model number 12301284). The changes affected the mass, hardness and thickness of the support legs.

Attempts had been made to test the design at various proving grounds, but due to complications in scheduling and cost, other alternatives were considered.

The Systems Simulation and Technology Division proposed a complete investigation of the system, consisting of various forms of analysis and simulation tests. The laboratory simulation test (shaker test) duplicates the forces encountered as the vehicle traverses various cross-country terrain profiles.

In addition to the laboratory simulation, a finite element analysis study was proposed for an analytical investigation of the structural integrity of the support kit. The finite element analysis would give insight to potential problem areas by evaluating the stress and deflections for the entire system. Various design modifications could be evaluated with this method to determine the best structural design. The analysis would support the application of strain gauging, which was also considered for the test. The complete investigation would be beneficial to present and future design modifications to the truck and machine gun support kit. The insight and experience gained would enable more efficient analysis on similar projects in the future.

Due to the limited amount of funds available, the test plans were reduced to a laboratory test consisting of various cross-country simulations. It was decided that the structural integrity could be determined from these tests. If a failure occurred, design modifications could be made and the tests would be resumed.

Three trucks are being tested with the machine gun support kit. They are the M342A2 (w/w) (2½-ton truck), M54A2 and M939 (5-ton truck). At the time of the writing of this report testing of the M342A2 (w/w) has been completed; therefore, the results and data presented in this report were obtained during the testing of the M342A2 (w/w) truck. These tests were conducted from 8 June 1987 to 25 August 1987. All vehicle instrumentation, data collecting and analysis were performed in coordination with AM General Corporation.

2.0. OBJECTIVE

The primary objective of this test was to evaluate the structural integrity of the truck cab and machine gun mount subject to dynamic forces induced when the vehicle traverses typical cross-country terrain profiles. These controlled laboratory tests are excellent means for providing information regarding the durability of the design and could reveal potential problem areas.

It should be recognized that these tests cannot replace field testing, however, the following is a list of several advantages to testing in a laboratory environment.

- Consistency--The tests can be repeated at a constant simulated vehicle speed.
- Variability--A wide variety of terrain profiles are available with simulation. Additionally, a wider combination of rough, mild, and smooth cross-country terrain conditions can be simulated.
- Dependability--The test scheduling is not affected by weather conditions. Major engine and transmission repairs are not anticipated.
- Location--Running the test on TACOM grounds is more convenient, avoiding the expense of transporting the vehicle and personnel travel.

3.0. CONCLUSIONS

Analytical simulation and laboratory testing is an effective alternative to field testing for 2½- and 5-ton trucks. A good cross spectrum of terrain/vehicle speed scenarios provided disturbance inputs to the vehicle which resulted in realistic dynamic conditions.

Several cab failures occurred throughout the 1,500-mile scenario which, if not caught during these laboratory simulations, probably would not have been noted until safety certification testing. Any effective repair on the cab will have a very good chance of surviving any future field testing.

The failures are described in Appendix A, including the total miles covered for each failure. The failures consisted of fracture cracks on the truck cab where the gun mount fixture was fastened to the cab.

These cracks were caused by the large torques induced on the machine gun mount fixture from typical disturbance accelerations during terrain travel. These instantaneous torques were a reflection of a very massive machine gun ring positioned above the truck cab. Major welding repairs were required for each failure so the cracks would not spread further when simulation was continued. The repair for the third failure consisted of applying rivets to support the internal cab cross brackets. A complete mission profile was simulated after this repair and resulted in no major failures, although a slight shift in the rivets on the driver's side was apparent.

The results presented here are based on the current 2½-ton truck and machine gun fixture made available for this test. Any further modifications made on the truck or machine gun mount may produce results which are different from those presented here.

4.0. RECOMMENDATIONS

If additional design modifications to the machine gun fixture and/or 2½-ton truck are considered, it is recommended that a similar test profile be implemented in the Physical Simulation Laboratory.

It is strongly recommended that the cab and machine gun mount structure be investigated by means of a Finite Element Analysis model. Such an analysis will yield important information about stresses and strain in the structure and will provide proper design guidance for maximum durability.

If the current design is considered acceptable, it is suggested that frequent inspections of the truck cab be required to maintain functional performance and safety.

5.0. DISCUSSION

A computer-based model of the truck was created by means of the Dynamic Analysis and Design System (DADS) methodology. The analytical simulation was performed using selected terrain profiles to "excite" the vehicle. From the results of the simulations, time histories were recorded representing the motion for each wheel spindle. The data collected was then transferred to TACOM's full-scale Physical Simulation Laboratory to provide the control signals to hydraulic actuators which reproduced these motions on the actual vehicle. Shown in Figure 5-1 is the 2½-ton truck attached to the simulator illustrating the actuator configuration.

The simulation process is described in Figure 5-2, which includes both the analytical and physical simulation portions of the process. The process starts with a selection of courses which are typical for a given vehicle. Data is obtained which describes the vehicle and an analytical

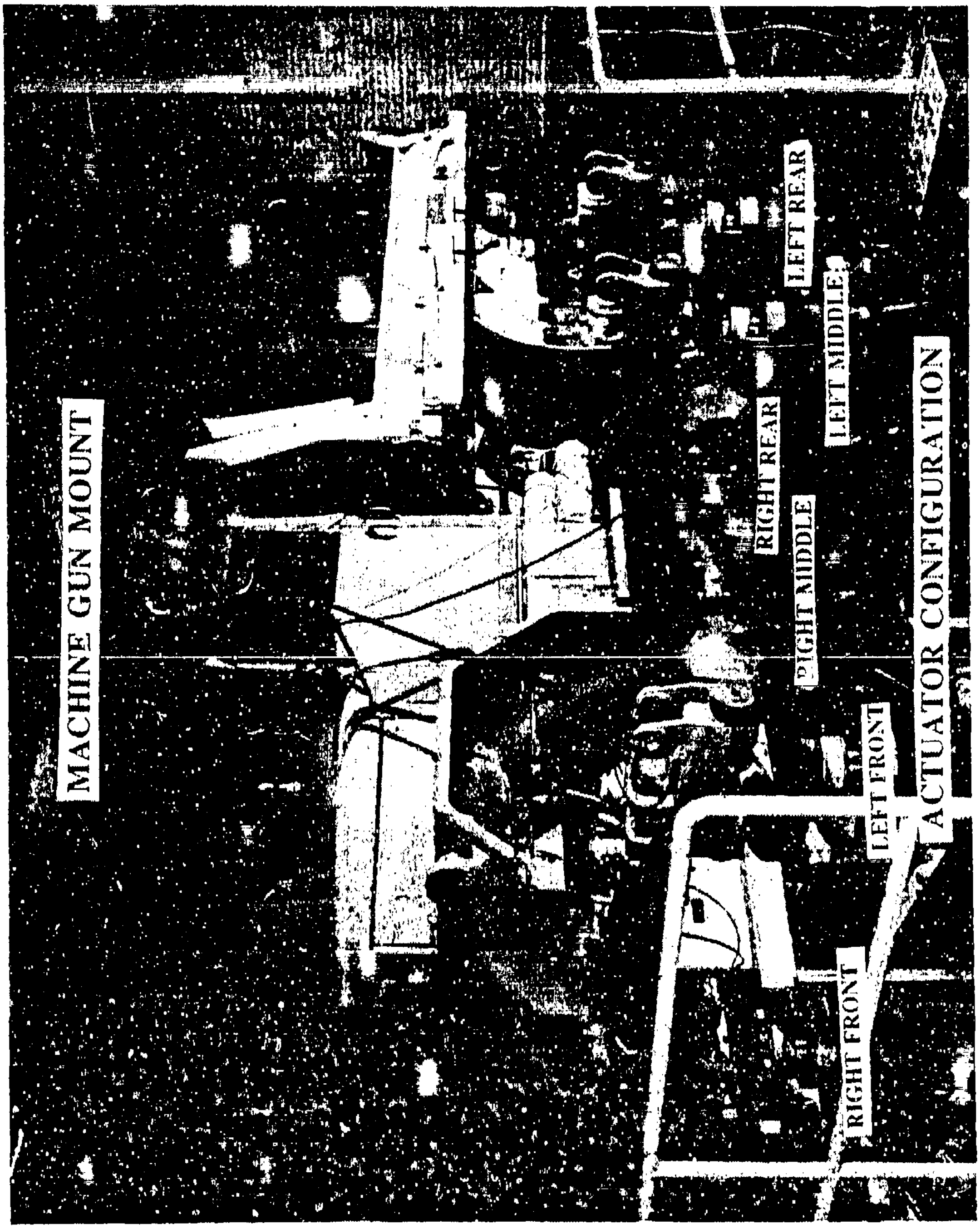


Figure 5-1. Machine Gun Mount/Actuator Configuration

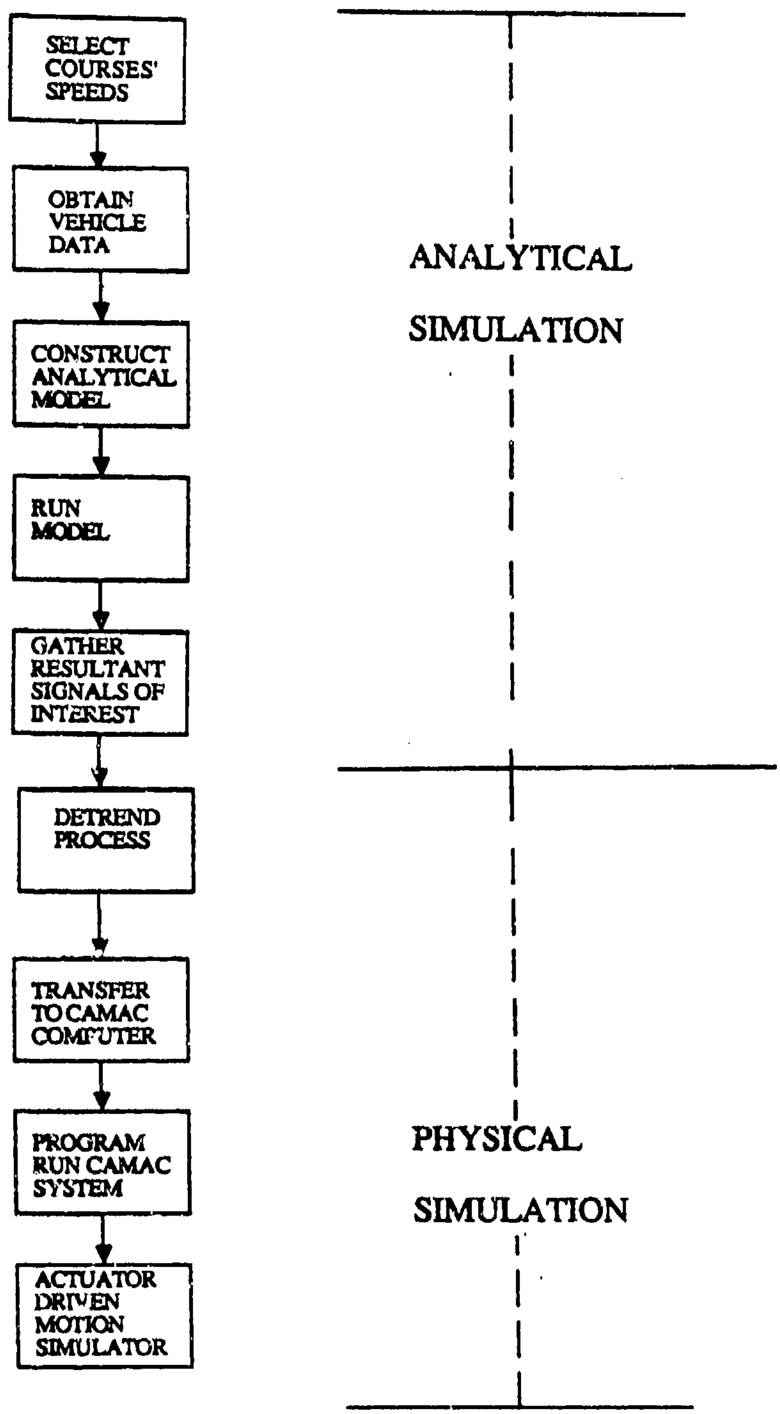


Figure 5-2. Simulation Process

model is constructed. Various simulations are executed until desired results are obtained. Time histories of interest are then gathered from the analytical results and are processed for physical simulation. A detrending process is used to convert the analytical time histories into waveform data which is in the limits of the physical simulator's capabilities. The waveform data is then transferred to a digital computer system which interacts with the hydraulic controllers of the physical simulator. The waveform data is then transferred to command signals for the physical simulator by means of digital to analog (d/a) conversion. This section describes the entire simulation process used for the test by discussing each stage of the process.

5.1. Course/Speed Selection

The System Simulation and Technology Division holds a large library of terrain profiles, encompassing a wide spectrum of surface characteristics. Figure 5-3 shows the distributions of surface roughness likely to be encountered in the field. The mission profile selected for this simulation is the so-called "tactical standard" mission, which has been used in many cross-country mobility simulations by TACOM and the Corps of Engineers Waterways Experiment Station. For a total travel of 1,500 miles, the mission profile gives the distribution of miles covered for each type of terrain (see Table 5-1).

The mission profile was followed for the truck simulations. Primary roads were excluded from the tests since the severity is less critical and because paved roads were traveled during the shipment of the truck from the systems technical support contractor. The entire mission profile was completed after the third failure. (See Appendix A.)

The vehicle speeds selected for each course are governed by the maximum speeds which an "average male" can endure for long periods of time (greater than 15 minutes). This degree of ride comfort was measured by evaluating the vertical absorbed power at the driver's seat. The absorbed power is a time-average rate of flow of energy into a vibrating (human) body. It characterizes vibration severity by correlating it to the response of a human body. It is a quantitative measurement in units of watts. Extensive past study indicates that crew personnel can comfortably withstand ride qualities that exhibit an absorbed power level of no more than 6 watts over extended periods of time. Therefore, the task was to choose the maximum vehicle speed which corresponds to the 6-watt absorbed power criterion. Results of human vibration studies are presented in "Analytical Analysis of Human Vibration," by Richard A. Lee and Fred Pradko.[1]

Based on previous data on vehicles similar to the 2½-ton truck, vehicle speeds were predicted for the 6-watt level, which was used as a starting point for the simulations. After several trial runs at various speeds the course/speeds shown in Table 5-2 were selected for the simulation test. The expected absorbed power was evaluated from the analytical model (par. 5.2). The model results show the absorbed power to

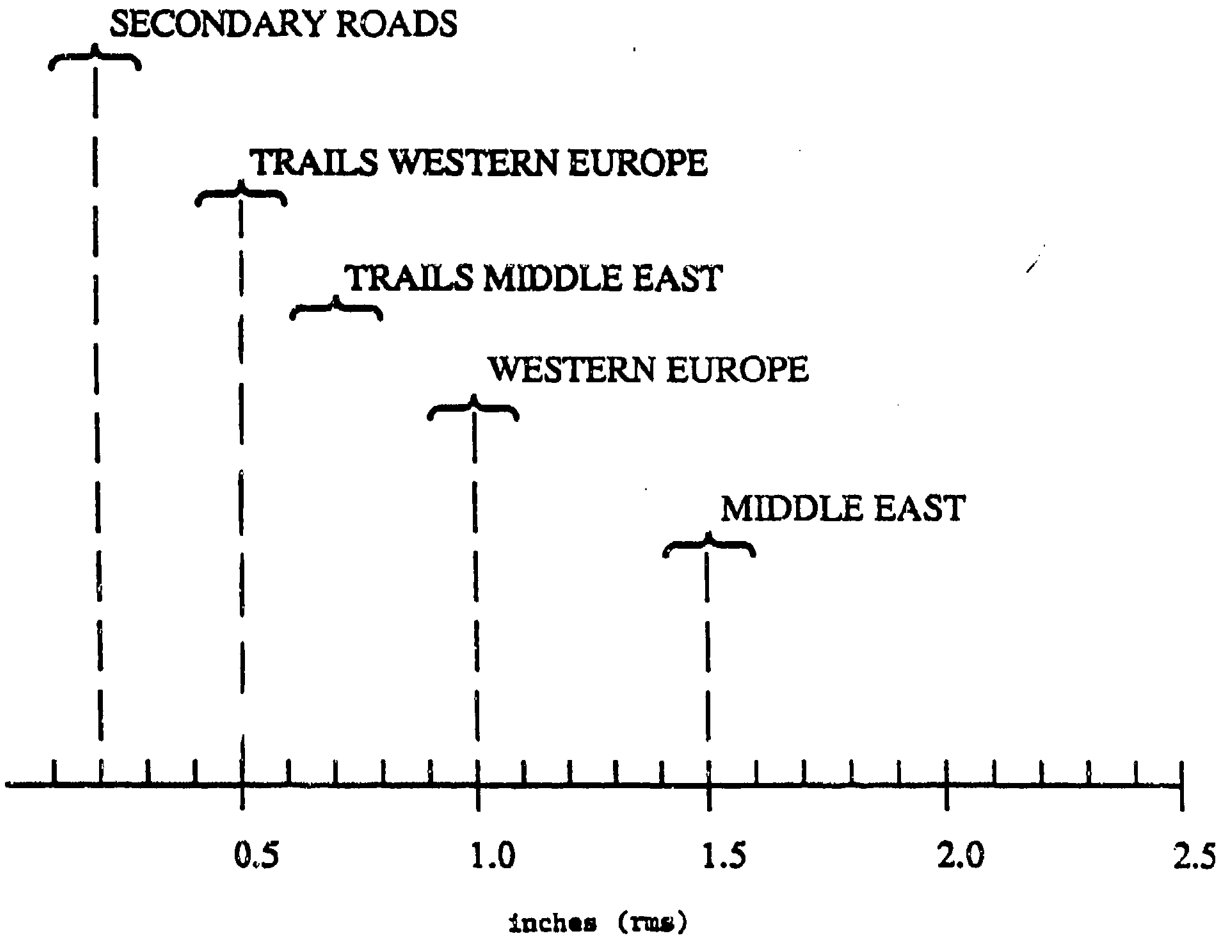


Figure 5-3. Surface Roughness

Table 5-1. Mission Profile for 1,500 Miles

Type of travel	% Travel	Miles
Primary Road*	20%	300*
Secondary Road	50%	750
Trails	15%	225
Off Road	15%	225
Totals	100%	1,500

*Excluded from the test.

Table 5-2. Course Simulations Used for 2½-Ton Truck

	Course	Speed (MPH)	Class	Course Length (FEET)	* Expected Absorbed Power (WATTS)
1.	Churchville 1	30.	Secondary Rd	300	-
2.	Churchville 1	45.	Secondary Rd	300	-
3.	Churchville 6	30.	Secondary Rd	300	-
4.	Churchville 6	45.	Secondary Rd	300	-
5.	APG 37	25.	Trail	400	5.0
6.	APG 9	14.	Off Rd	300	6.3
7.	APG 11	9.3	Off Rd	400	4.9
8.	APG 11	9.8	Off Rd	400	5.0
9.	APG 12	10.	Off Rd	300	6.2
10.	APG 29	8.5	Off Rd	300	5.1
11.	Ft Knox	12.	Off Rd	400	5.0

* Evaluated from analytical model results

approach but not exceed the 6-watt level. Secondary roads are not rough enough to produce severe vibrations at reasonable speeds, therefore, we did not run the simulation near the 6-watt level on these surfaces.

5.2. Analytical Simulation

The DADS methodology was used for the truck simulations. DADS was developed jointly by the University of Iowa and TACOM. Vehicle parameter data required for the assembly of the model include inertia, mass properties, geometry, and external forces applied. DADS simulates a system as a collection of rigid bodies connected by user-selected joints, constraints, and springs to predict forces, torques, and motion time histories when subjected to prescribed external forces (induced by terrain profiles).

Once a working model has been developed, a terrain disturbance and vehicle speed are selected (as mentioned in par. 5.1.), and a simulation is conducted. Several variables of interest are monitored. These include pitch rate, ride comfort, and spindle positions and rates. If the analytical simulation produces close to 6 watts of absorbed power, then the simulation is selected for output generation of control signals for the laboratory motion simulator. If this criterion is not met, a different vehicle speed is selected and another simulation is performed. Most courses took several trial runs before the final simulations were selected. Video animations were made from some of the simulations so studies could be made on the general dynamic behavior of the truck.

5.3. Detrending Process

The detrending process is used to convert the time histories generated from the analytical simulation to wave forms which are confined within the dynamic range of the simulator. The detrending process consists of a numerical technique which is used to eliminate the "trending" excursions from the raw spindle position data. The algorithm used for this technique is described in the National Aeronautics and Space Administration (NASA) Contractor Report, NASA CR-659.[2] The results of this technique give similar characteristics to a 2-pole, high-pass filter except that it has no phase shift property. Figures 5-4 and 5-5 illustrate the results of the detrending process consisting of the front right spindle position for two different course simulations. The dashed lines represent the raw time history function generated from the model. The solid lines are the results of the detrending process. The plateaus were added to the beginning and end of the function because the detrending algorithm requires a past and a future portion of the input function to determine its current iterative value. As can be seen, the detrending process has eliminated the low-frequency content from the data. The resulting filtered waveforms have zero mean and no duration monotonic components. The resulting function can now be converted to a command signal for the actuators of the physical simulator.

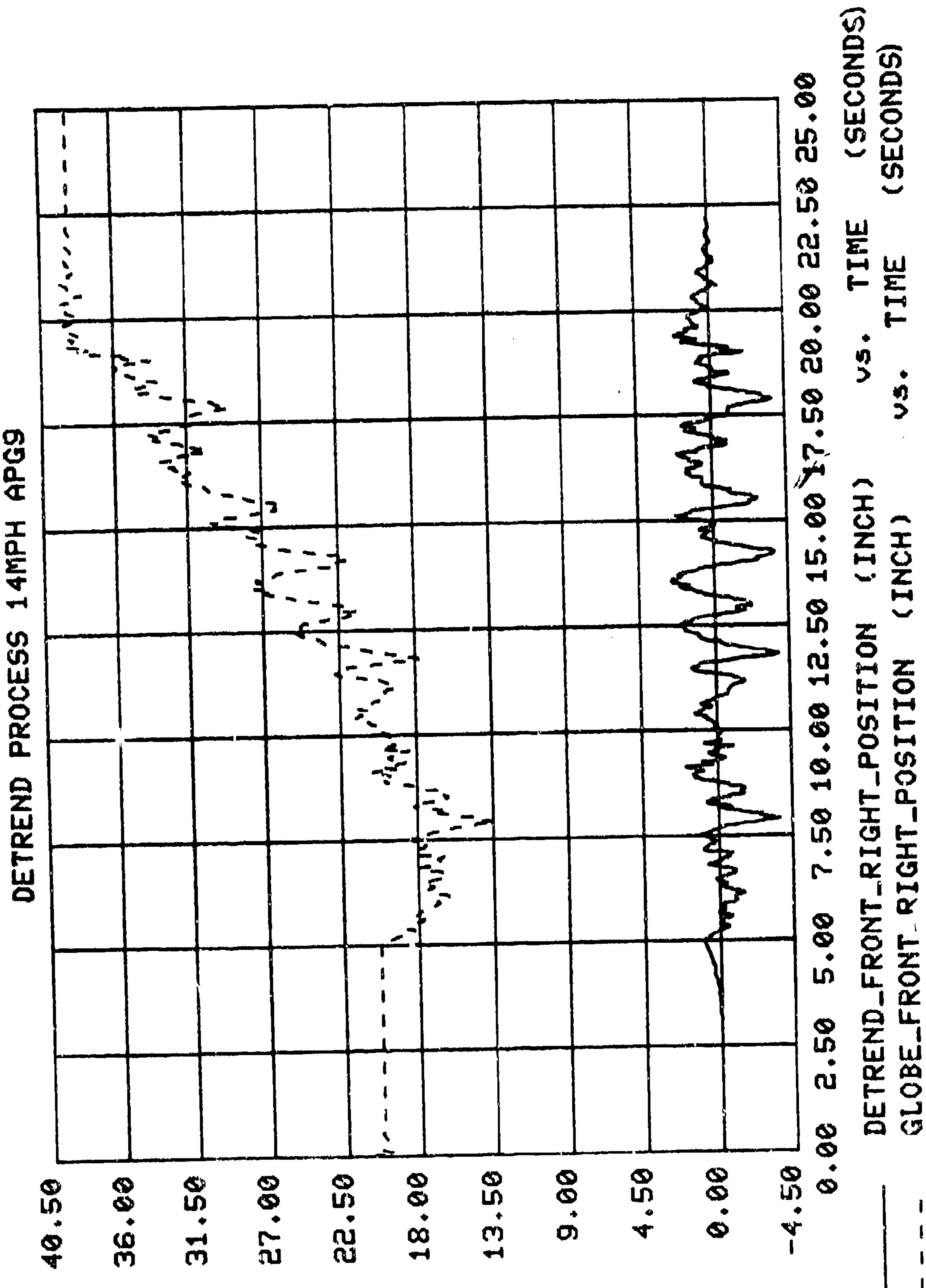


Figure 5-4. Detrend Process/14 mph,APG9

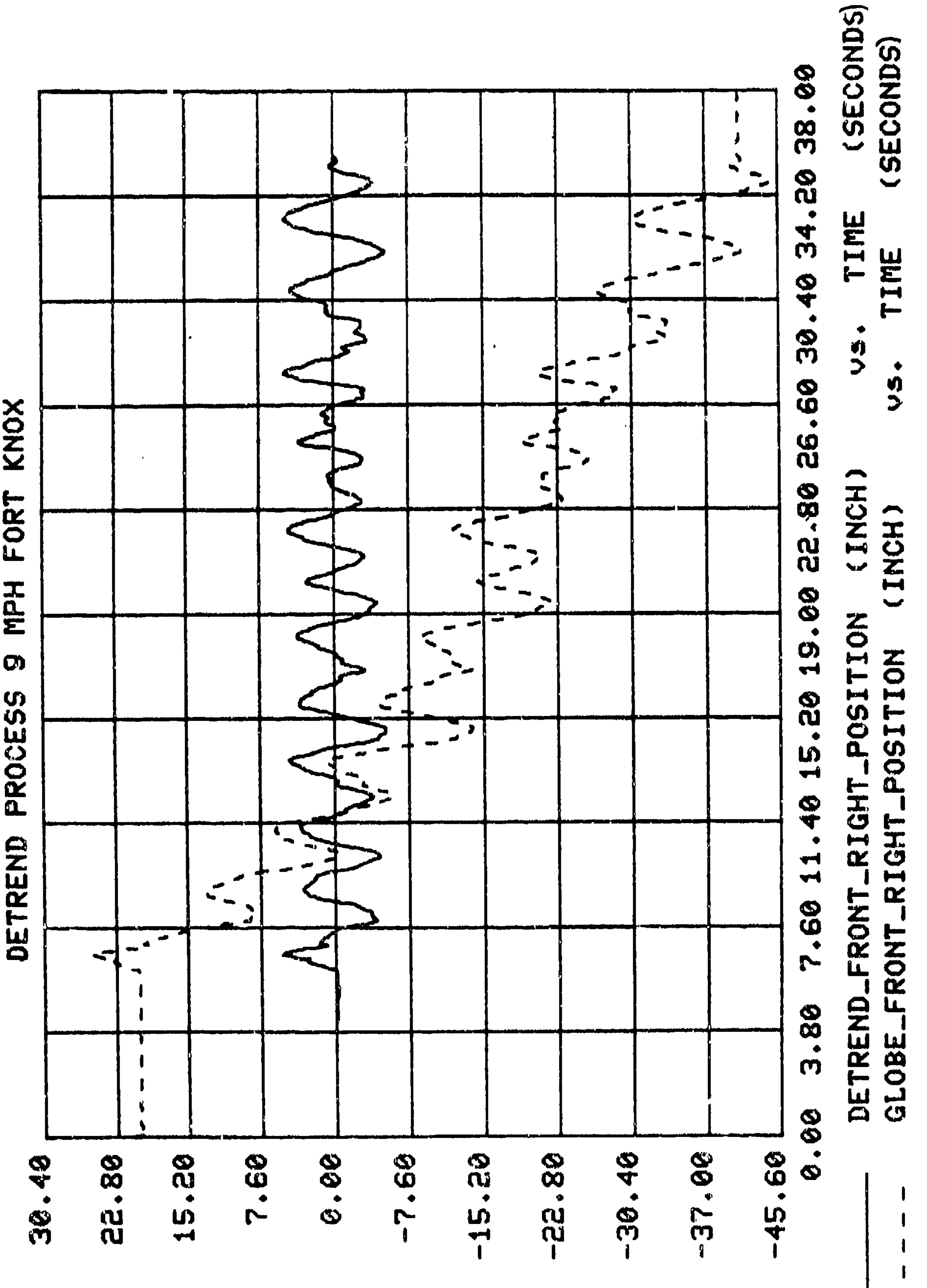


Figure 5-5. Detrend Process/9 mph, Fort Knox

5.4. Physical Simulation

The resultant waveforms, which consist of the spindle position time histories from the detrending process, were transferred to TACOM's full-scale Physical Simulation Laboratory to provide the control signals to the hydraulic actuators which reproduce these motions on the vehicle.

A block diagram is shown in Figure 5-6 which illustrates the motion simulator configuration. The heart of this system is the Computer Automated Measurement and Control (CAMAC) system which is used for generating the input command signals for the physical simulator and recording the acceleration data. CAMAC is an internationally accepted laboratory industry standard used for computer-controlled testing.

The command signals generated from CAMAC are sent through a filter device. The filter device is a fully modular and programmable signal-conditioning system. It is programmed to function as a low-pass butterworth filter with a breakpoint of 8 hertz for this application. After many test runs it was found that any frequency content beyond 8 hertz had very little influence on the accelerations in the truck cab area; in fact the absorbed power was measured to be the same without filtering. This happens because the suspension absorbs the higher frequencies. Since this was not a suspension test but rather a test considering forces induced on the truck cab, the command signals were filtered to eliminate excess wear on the simulator and reduce any undesirable noise which may be present at any time.

The output of the filters is passed as input to the electrohydraulic system which drives the actuators. The electrohydraulic system consist of a three-stage servo valve system with position feedback control for each actuator. The position sensors used for the main feedback loop contain Linear Variable Differential Transducers (LVDTs) which measure the displacement of the actuators. Some of the laboratory simulator characterics are as follows:

- Three degrees of freedom: Pitch, roll and vertical motions. (Truck cab senses side-side and fore-aft translational components due to roll and pitch motions respectively.)
- Bandwidth: 4 Hertz
- Maximum actuator acceleration: 5 g
- Actuator Displacement: +/- 8 inch

Although it was AM General's task to record data, additional data were recorded by Systems Simulation and Technology Division engineers using both the strip chart recorder and the analog to digital (a/d) converters on the CAMAC system. Some of the results are presented in Appendix B, including measurements with a Fourier analyzer.

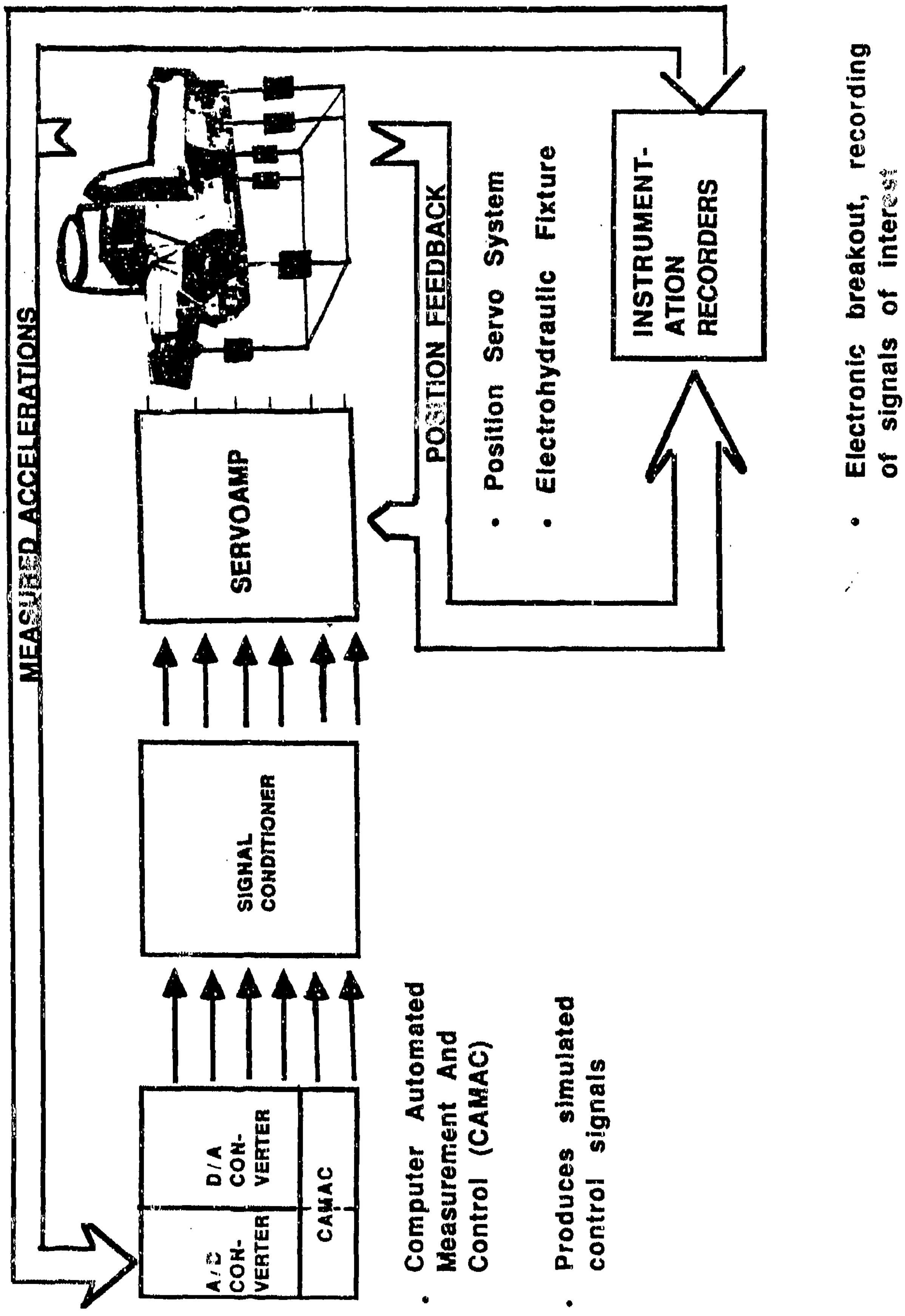


Figure 5-6. Physical Simulation Block Diagram

The Systems Simulation and Technology Division used CAMAC to provide all the control and data acquisition functions for the motion simulator. The computer program used for the CAMAC system to provide real-time analog control signals was developed from modifying a CAMAC program used previously for an M9 Armored Combat Earthmover (ACE) hatch test project. The M9 hatch project was conducted last year and in many ways it was similar to the truck simulation testing (for more information, see RD&E Center Technical Report No. 13228[3]). The CAMAC program written for the truck simulation testing has the following features:

- Provides real-time control (provides command signals representing terrain simulation).
- Provides statistical analysis of command signals (maximum/minimum, maximum/minimum slopes, etc.).
- Includes safety features (Avoids overloads, extreme velocities, improperly selected scenarios, initialization and shut down procedures.)
- Runs course simulations in any desired sequence and number of iterations by a convenient menu layout.
- Samples data when selected by preset or by interactive switch, accumulates sampled data files.
- Keeps records (continuously keeps record of miles traveled on each course simulation).
- Displays a screen format showing a continuous status of the simulation (iterations, course, time on each course, etc.).

Most of the analytical simulations were two-dimensional in nature and had pitch and vertical motion. A pseudo three-dimensional laboratory simulation was created by applying a small time delay between the left and right side which effectively added roll motion to the vehicle. The time delay varied from .06 to .12 seconds depending on the simulation characteristics. This procedure was done on the two-dimensional simulations so that lateral motion would be present in the cab area making the vehicle motion more typical of a terrain traveling environment.

5.5. Simulation Results

The laboratory simulation testing worked very well in pointing to the structural problem areas of the machine gun mount fixture. The simulation test is representative of typical terrain travel and gives an indication of where future failures may occur. Repairs were made on the truck as the simulation test was conducted and are described in Appendix A.

The dynamic characteristics of the actual truck motions were predicted very well from the analytical simulation model. Table 5-3 shows the

Table 5-3. Absorbed Power Results

	Course	Speed	Absorbed Power * Expected	(Watts) Measured
1.	CHV 1	30.	-	4.0
2.	CHV 1	45.	-	3.8
3.	CHV 6	30.	-	1.9
4.	CHV 6	45.	-	3.1
5.	APG 37	25.	5.0	4.0
6.	APG 9	14.	6.3	3.4
7.	APG 11	9.3	5.0	4.5
8.	APG 11	9.8	5.0	5.5
9.	APG 12	10.	6.2	7.0
10.	APG 29	8.5	5.1	5.0
11.	Ft. Knox	12.	5.0	4.1

* Evaluated from analytical model results

results of the absorbed power measurements and the predicted values for each course simulation.

Some of the data recorded from the simulation testing is presented in Appendix B, including the time histories measured from each course simulation. A Power Spectral Analysis was made from the measured data for the front left spindle acceleration and vertical seat acceleration for each course. Power spectrums give an indication of the frequency content of the simulation and are used to characterize a given course and speed.

LIST OF REFERENCES

1 Lee, Richard A. and Pradko, Fred, "Analytical Analysis of Human Vibration," Technical Report from Automotive Engineering Congress, Detroit, MI (January 8-12, 1968)

2 Van Deusen, B.D., "A Statistical Technique for the Dynamic Analysis of Vehicles Traversing Rough Yielding and Non-yielding Surfaces," NASA Contractor Report, NASA CR-659 (March, 1967)

3 Zywiol, Harry, "M9 Driver's Hatch Simulation," RD&E Center Technical Report No. 13228, U.S. Army Tank-Automotive Command, Warren, MI (December, 1986)

APPENDIX A

RECORD OF FAILURES

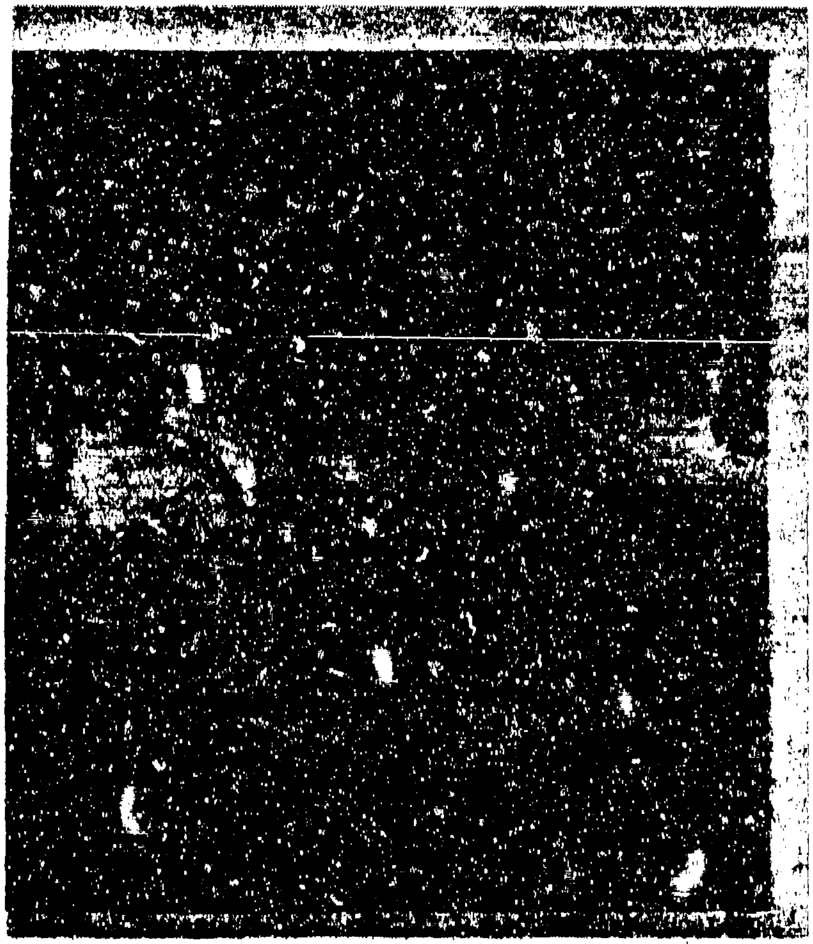
The truck and machine gun mount fixture were inspected frequently between simulations for any signs of failures. The following is a record of the failures and repairs reported on the 2½-ton truck during simulation testing.

FAILURE 1

Small fracture cracks have appeared around both cross brackets near the rear support legs in back of the truck cab. The failure was assumed to be caused by poor welds. Repairs were made by grinding down the old welds and patch welding over the surface (electrode arc welding). See photo on this page and the next.

MILE COVERAGE ON FAILURE 1

TERRAIN TYPE	MILES
Secondary Roads	0.0
Trails	12.7
Off Roads	56.9
Total Miles =	69.6

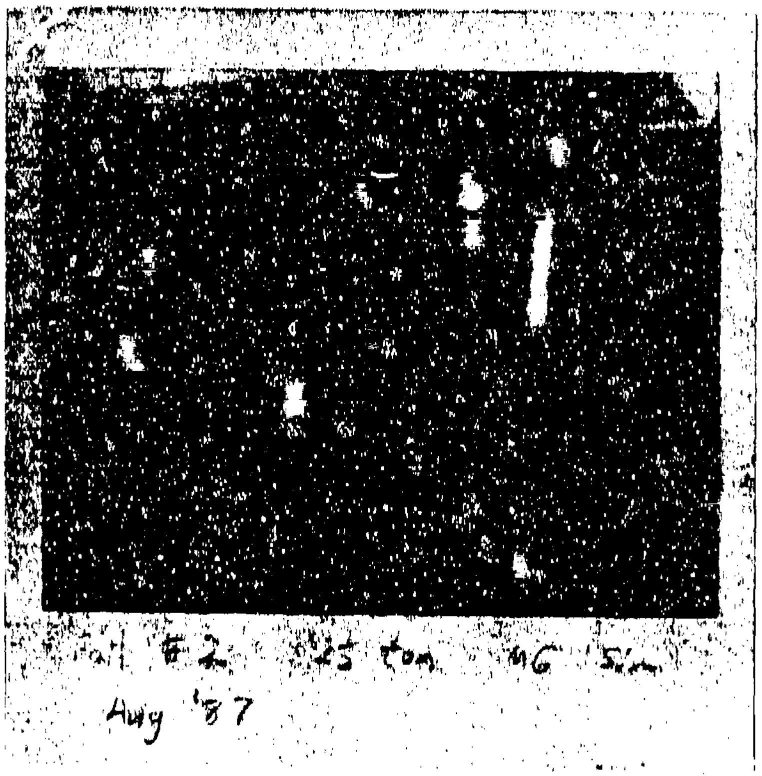


FAILURE 2

Large fracture cracks (3-5 inch) have appeared on the dashboard near the front support leg. The failure was repaired by applying an angle patch and welding. At this time the front support leg fixture was very loose. New bolts were used with lock washers.

MILE COVERAGE ON FAILURE 2

TERRAIN TYPE	MILES
Secondary Roads	0.0
Trails	48.3
Off Roads	185.2
Total Miles =	233.5



FAILURE 3

Fracture cracks resurfaced where failure 1 has occurred around the cross brackets near the rear support legs. The failure was repaired by applying four rivets to each cross bracket for support.

MILE COVERAGE ON FAILURE 3

TERRAIN TYPE	MILES
Secondary Roads	104.9
Trails	65.8
Off Roads	185.2
Total Miles =	355.9

The mission profile was completed after the third failure was repaired with rivets. The simulation corresponds to 1,200 miles of travel after the third failure. No additional cracks appeared, however, the support fixture became loose and the rivets on the driver's side were apparently shifted.

MILE COVERAGE TOTAL

TERRAIN TYPE	MILES
Secondary Roads	854
Trails	290
Off Roads	401
Total Miles =	1,545

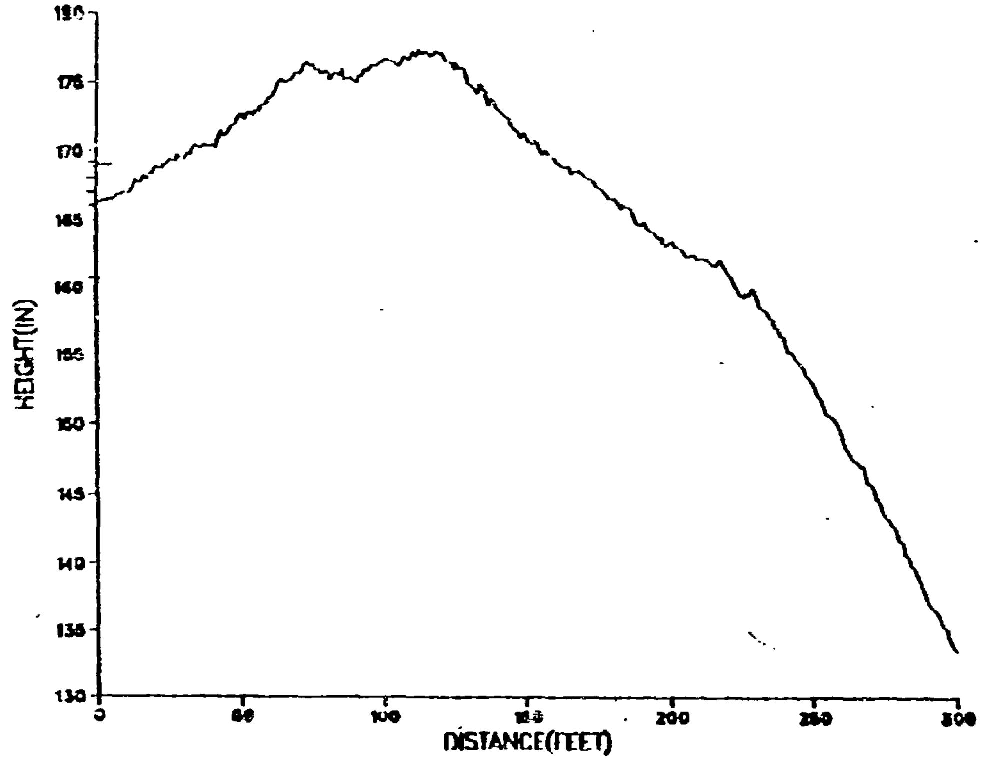
APPENDIX B

DATA SECTION

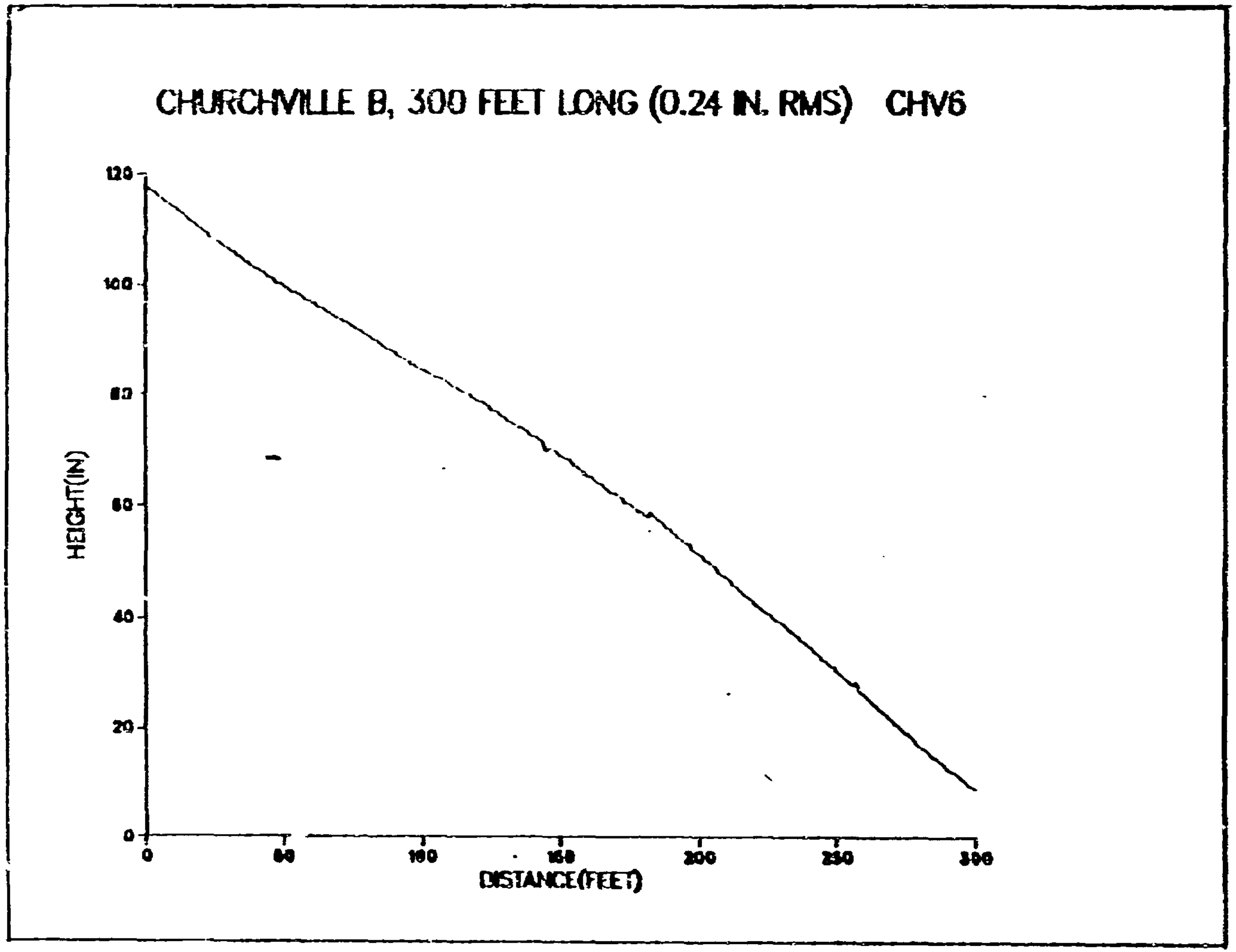
COURSE PROFILES

COURSE PROFILE CHURCHVILLE 1

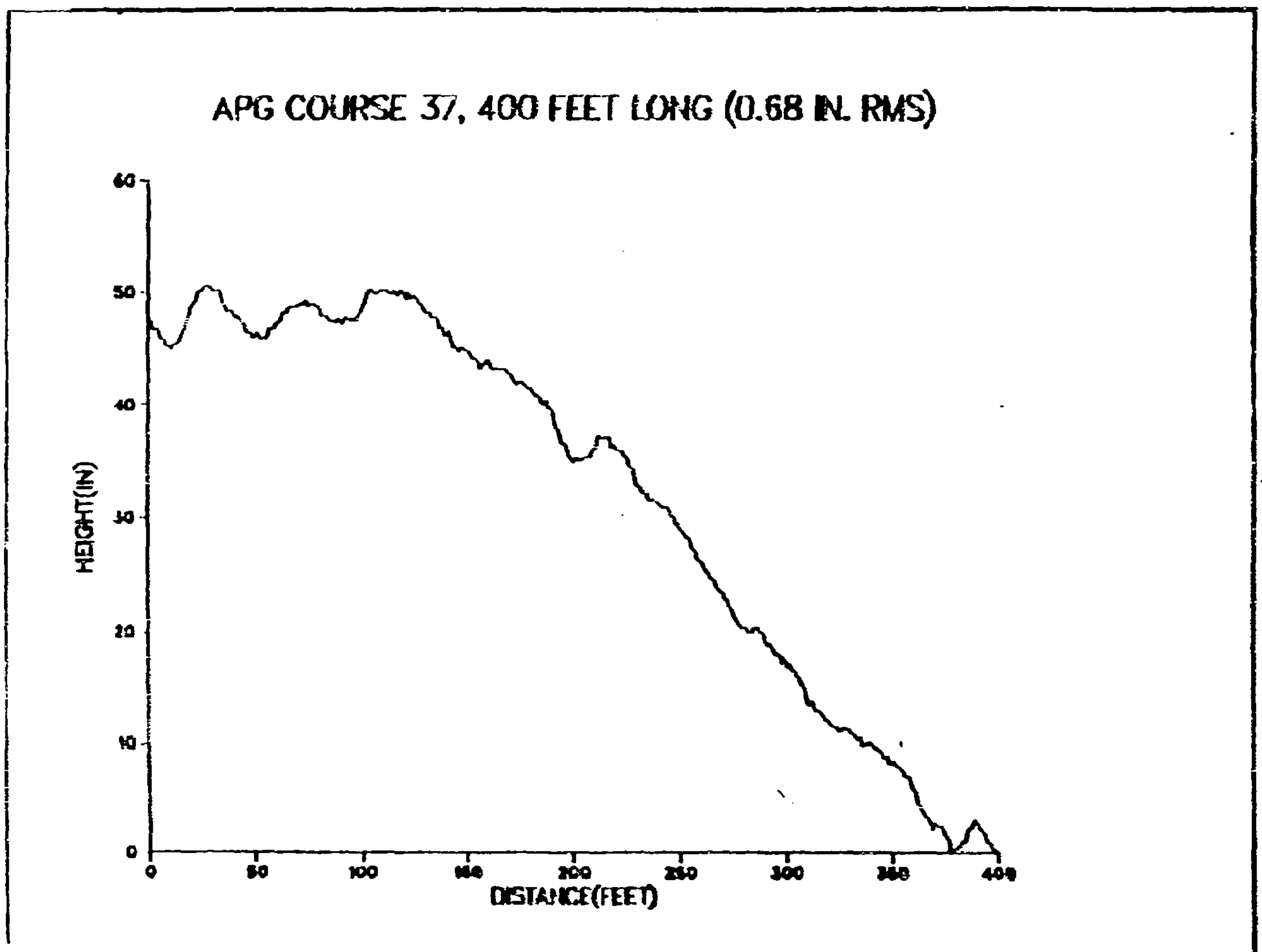
CHURCHVILLE B, 300 FEET LONG (0.36 IN. RMS) CHV1



COURSE PROFILE CHURCHVILLE 6



COURSE PROFILE APG-37



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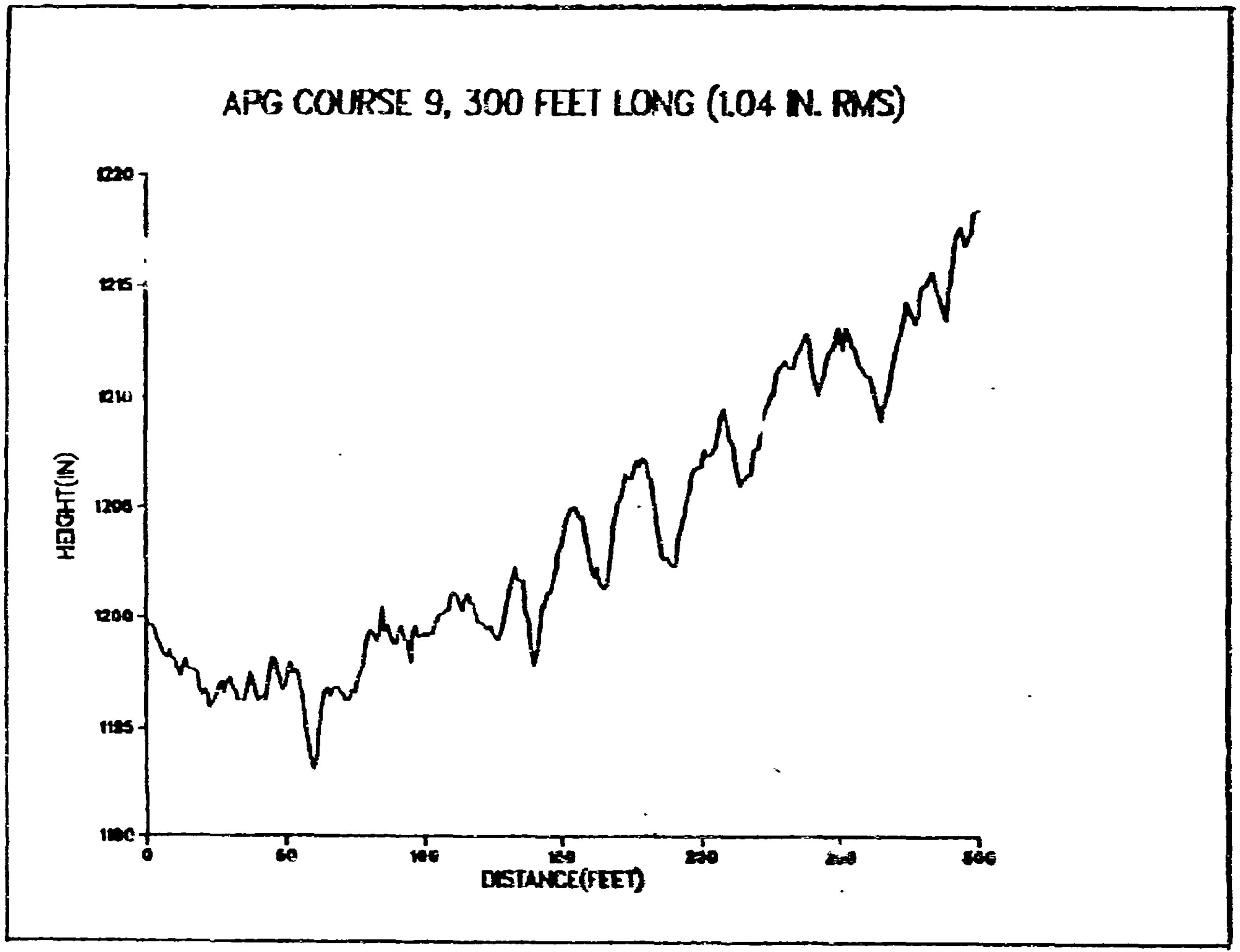

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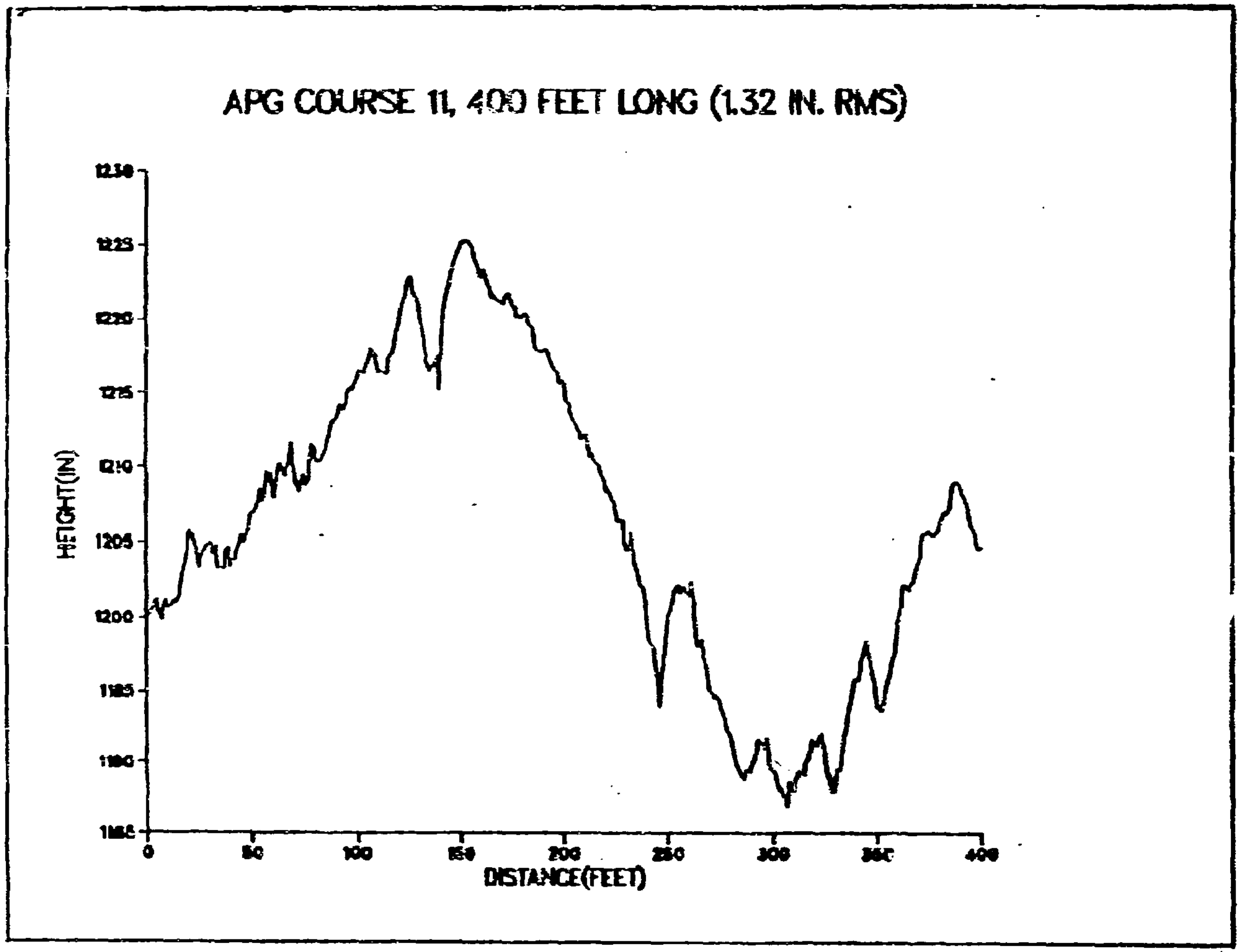

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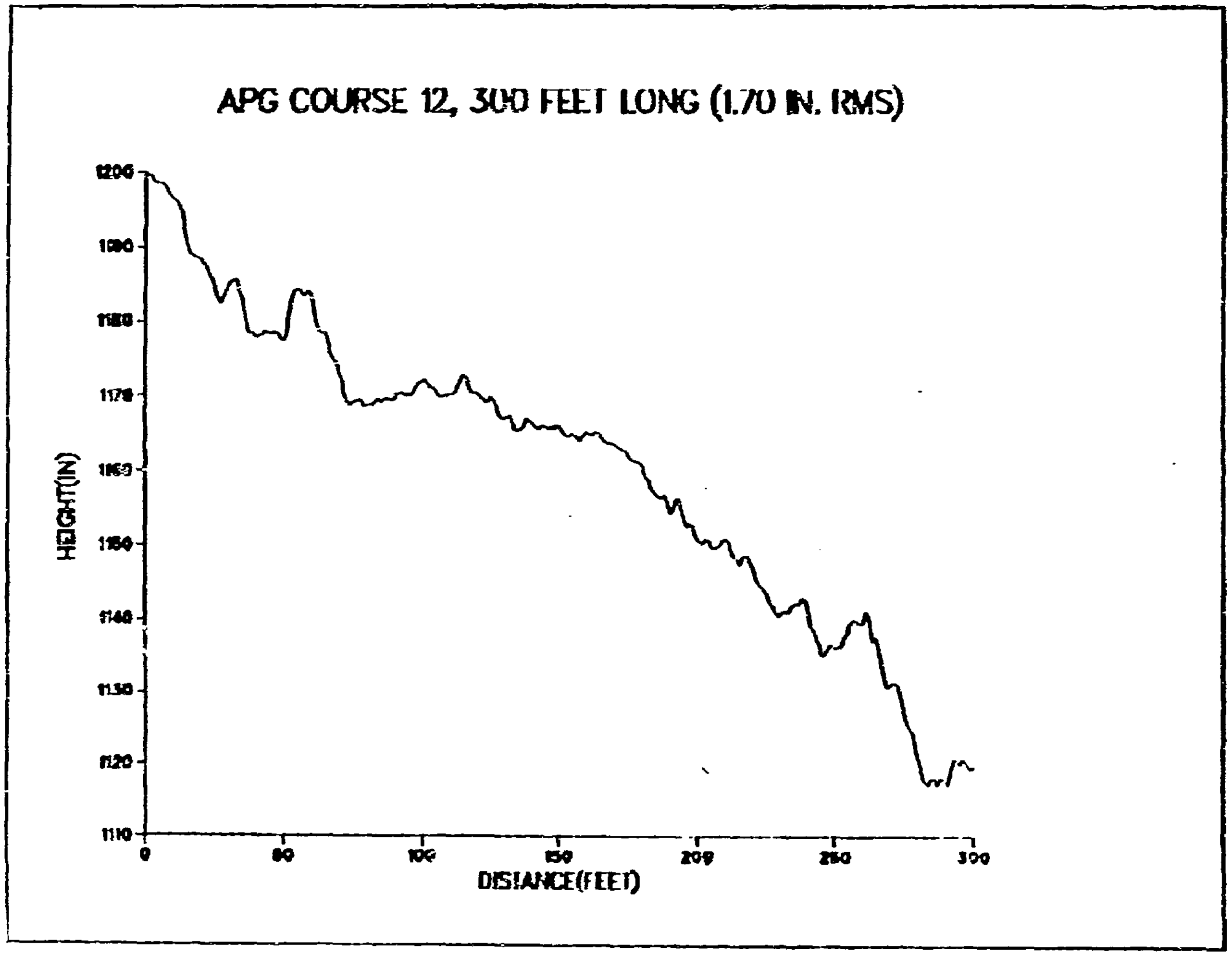

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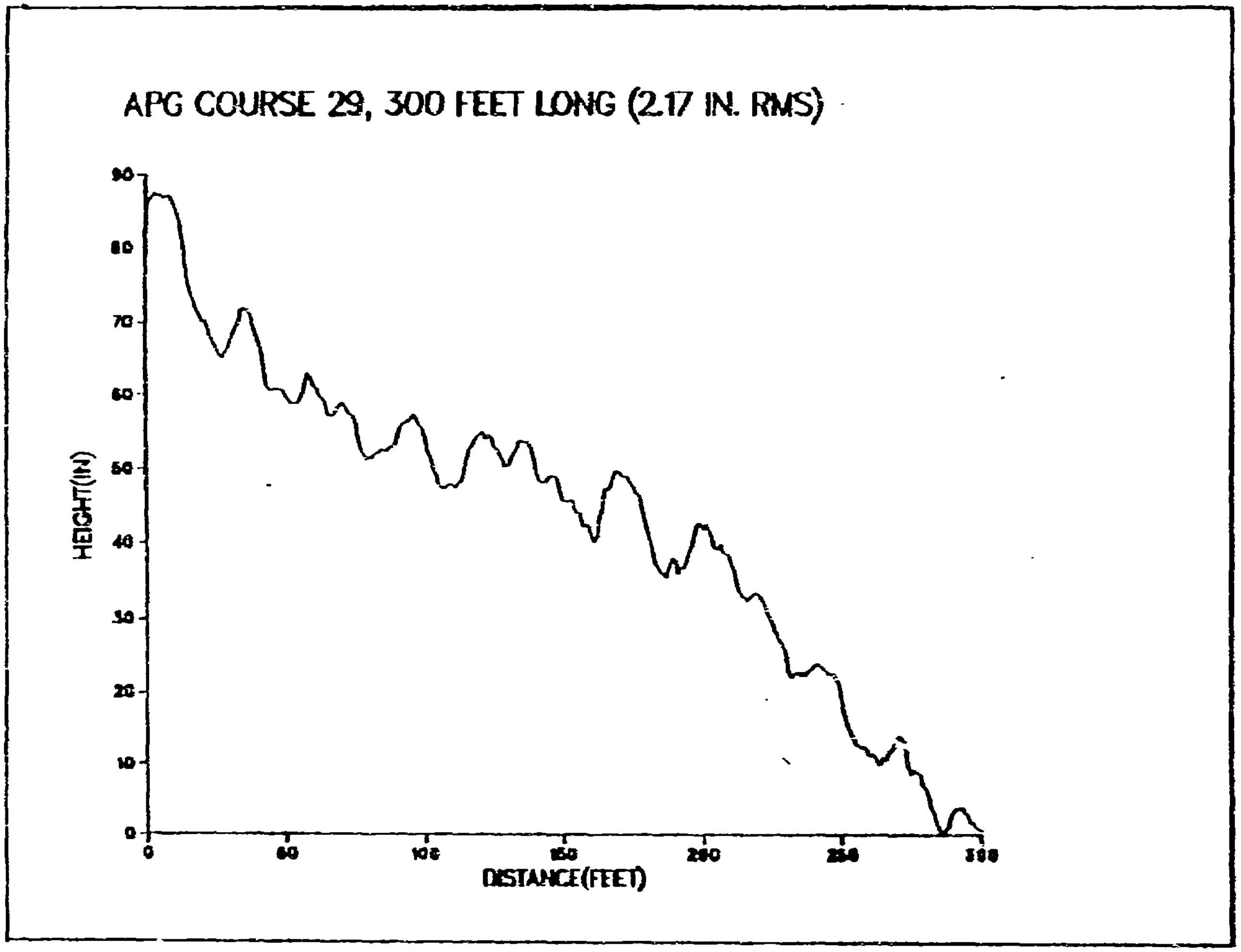
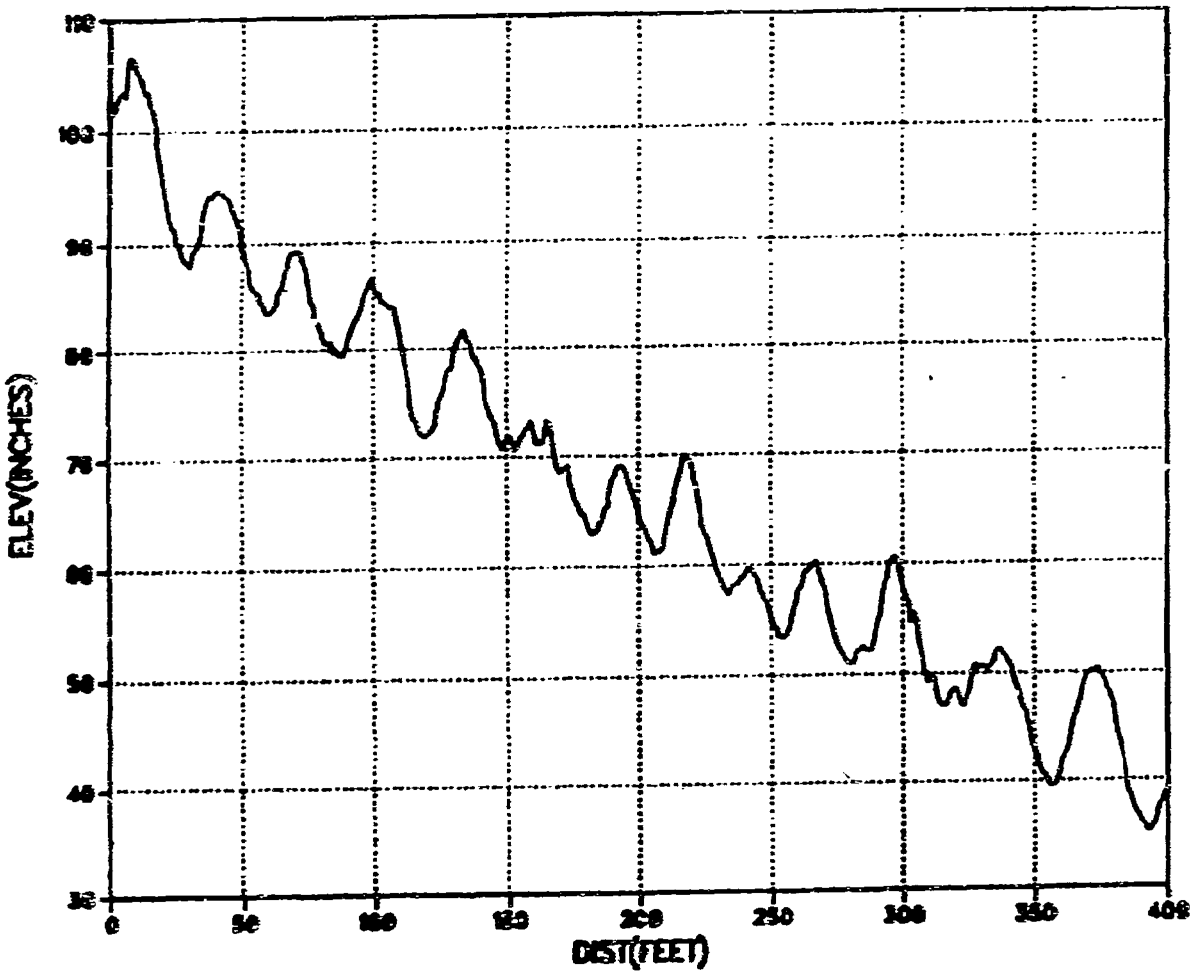
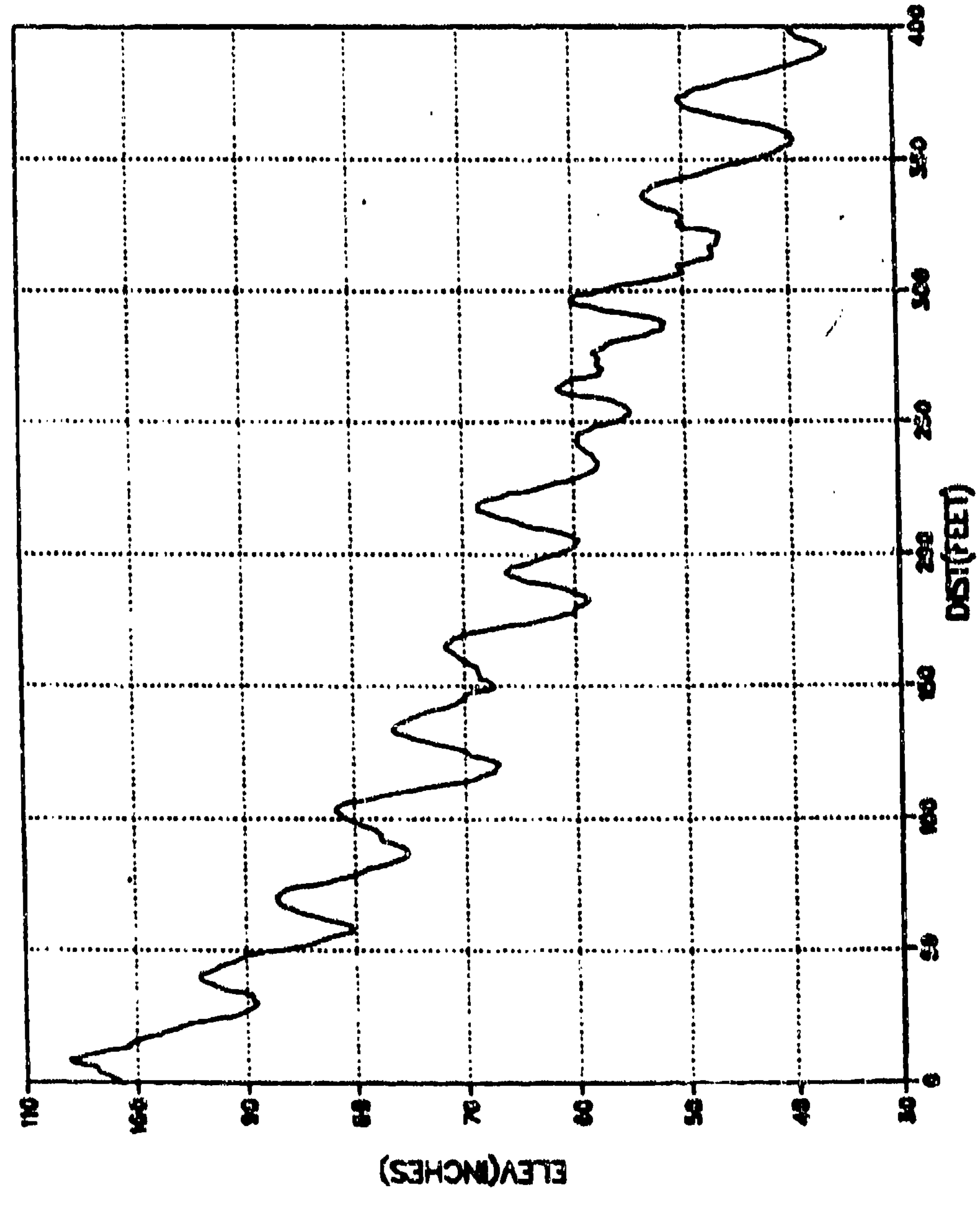


COURSE PROFILE FORT KNOX - RIGHT

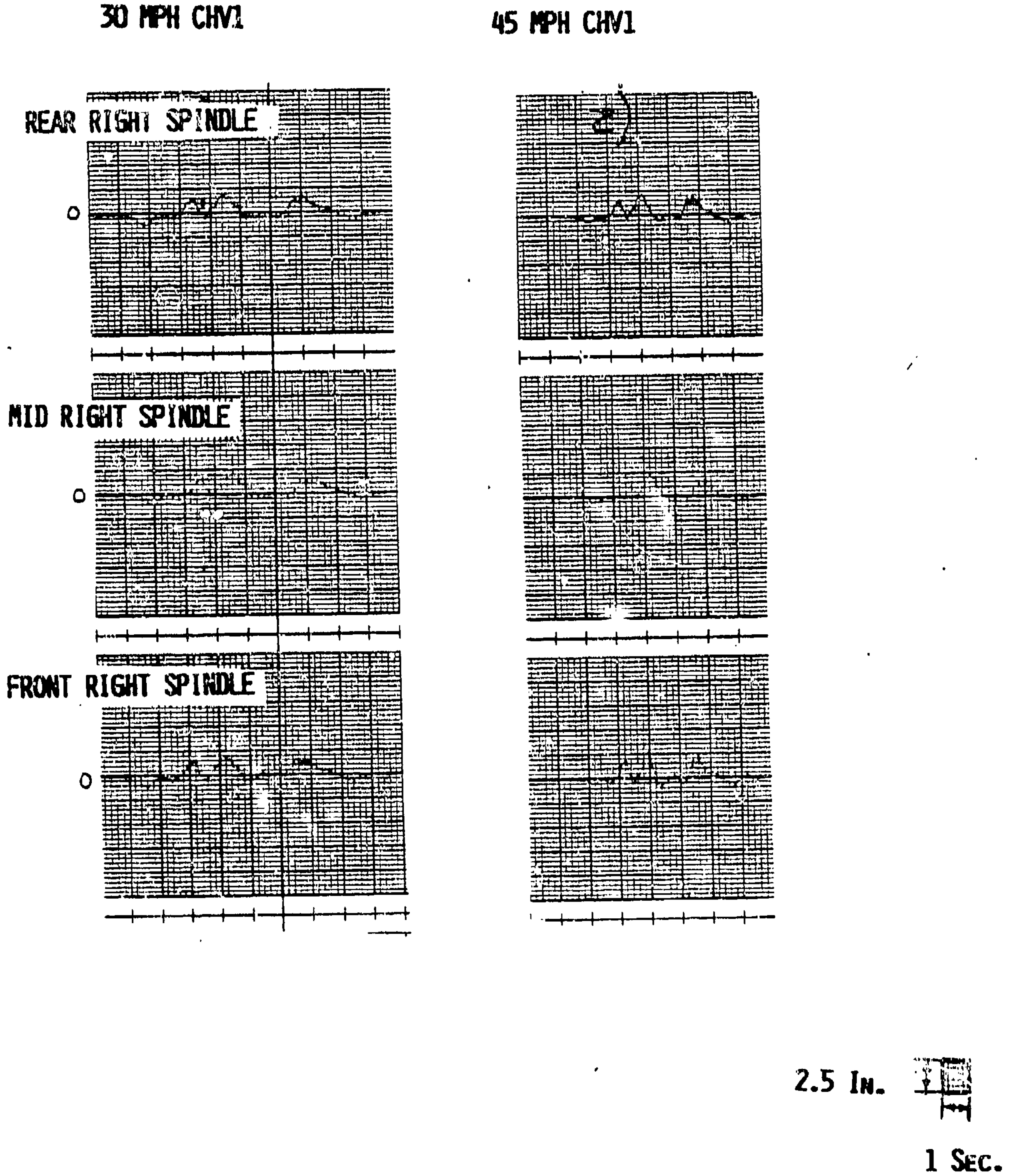


COURSE PROFILE FORT KNOX - LEFT

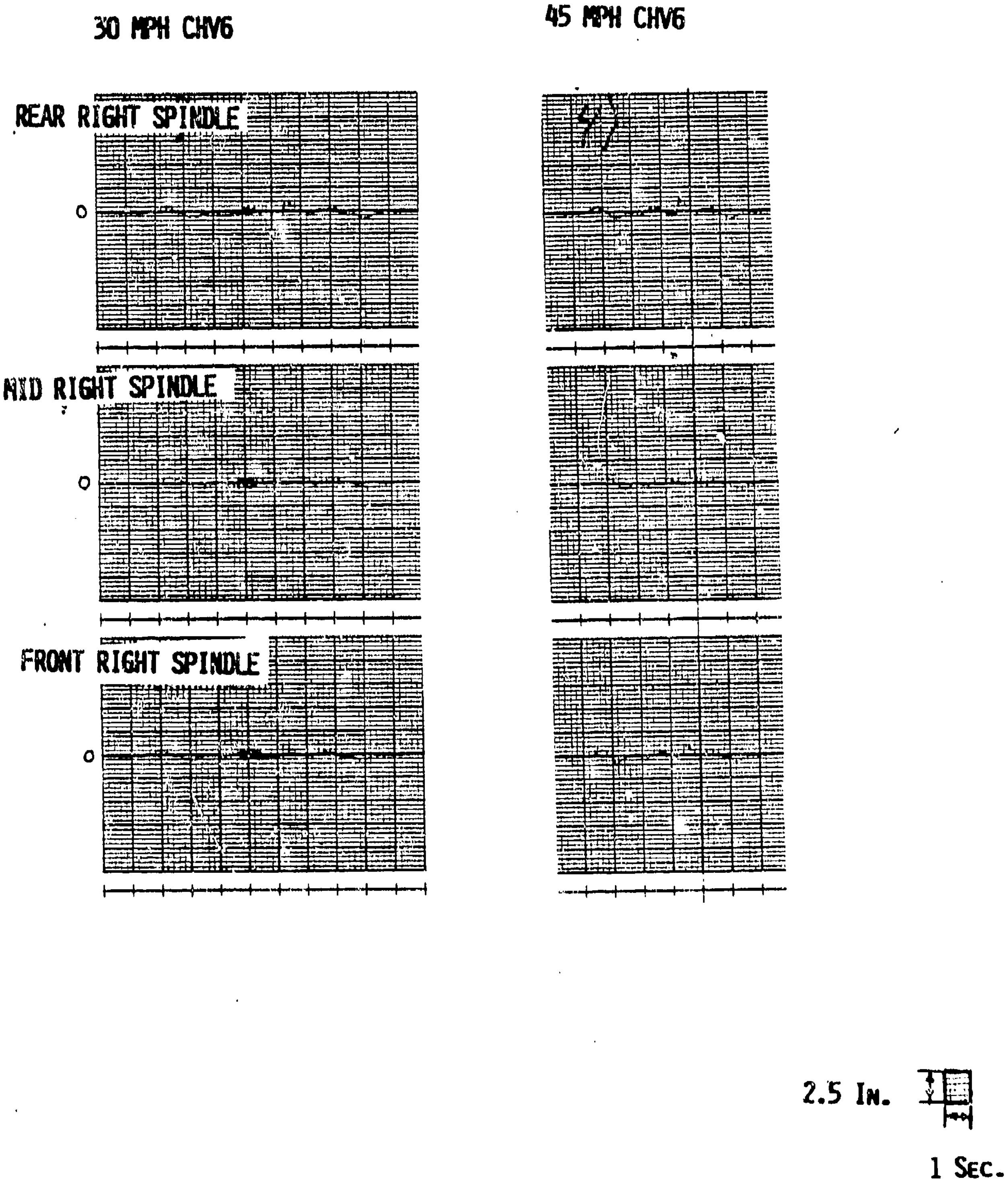


MEASURED ACTUATOR POSITION RESPONSE

MEASURED ACTUATOR POSITION RESPONSE

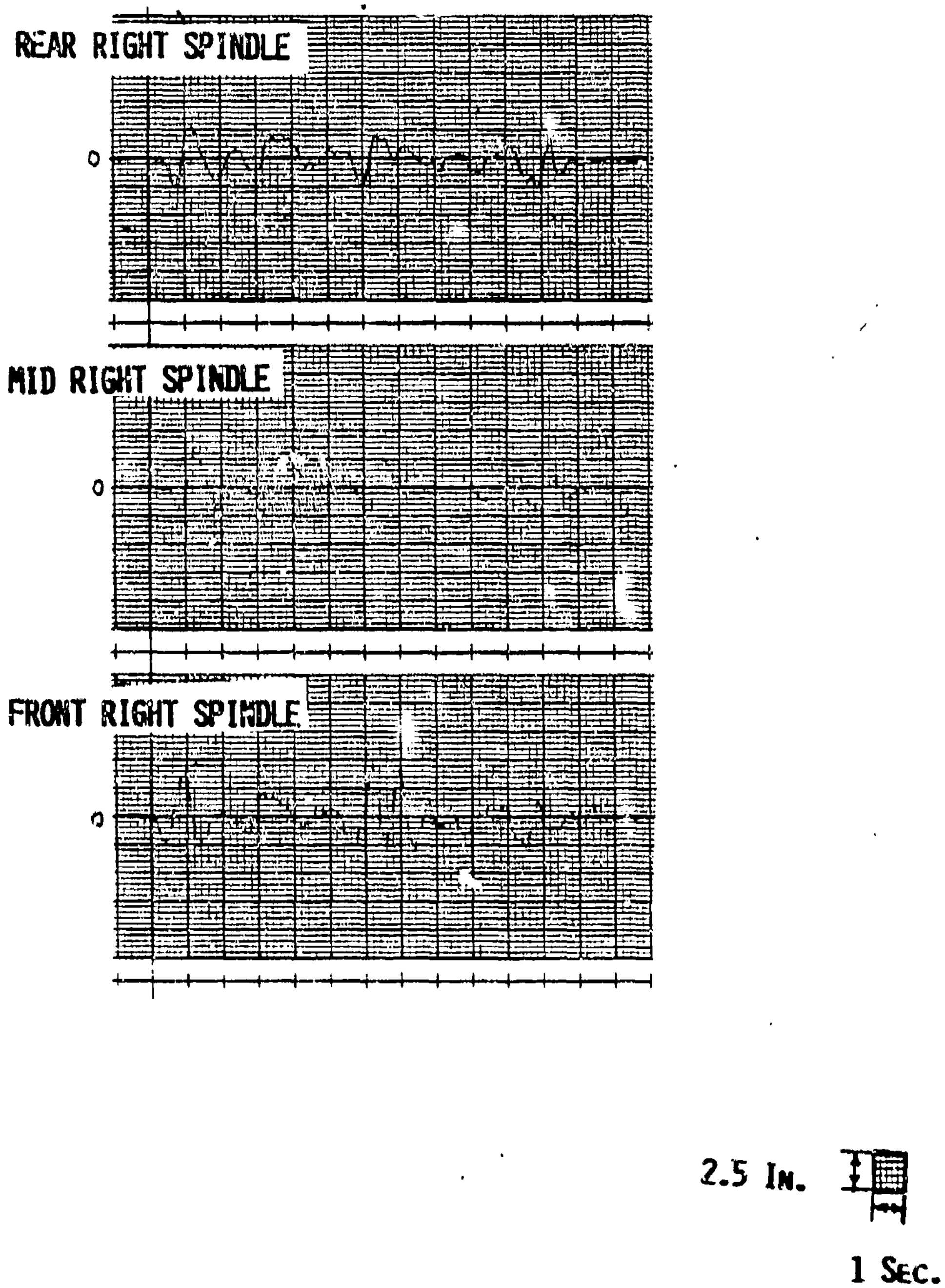


MEASURED ACTUATOR
POSITION RESPONSE



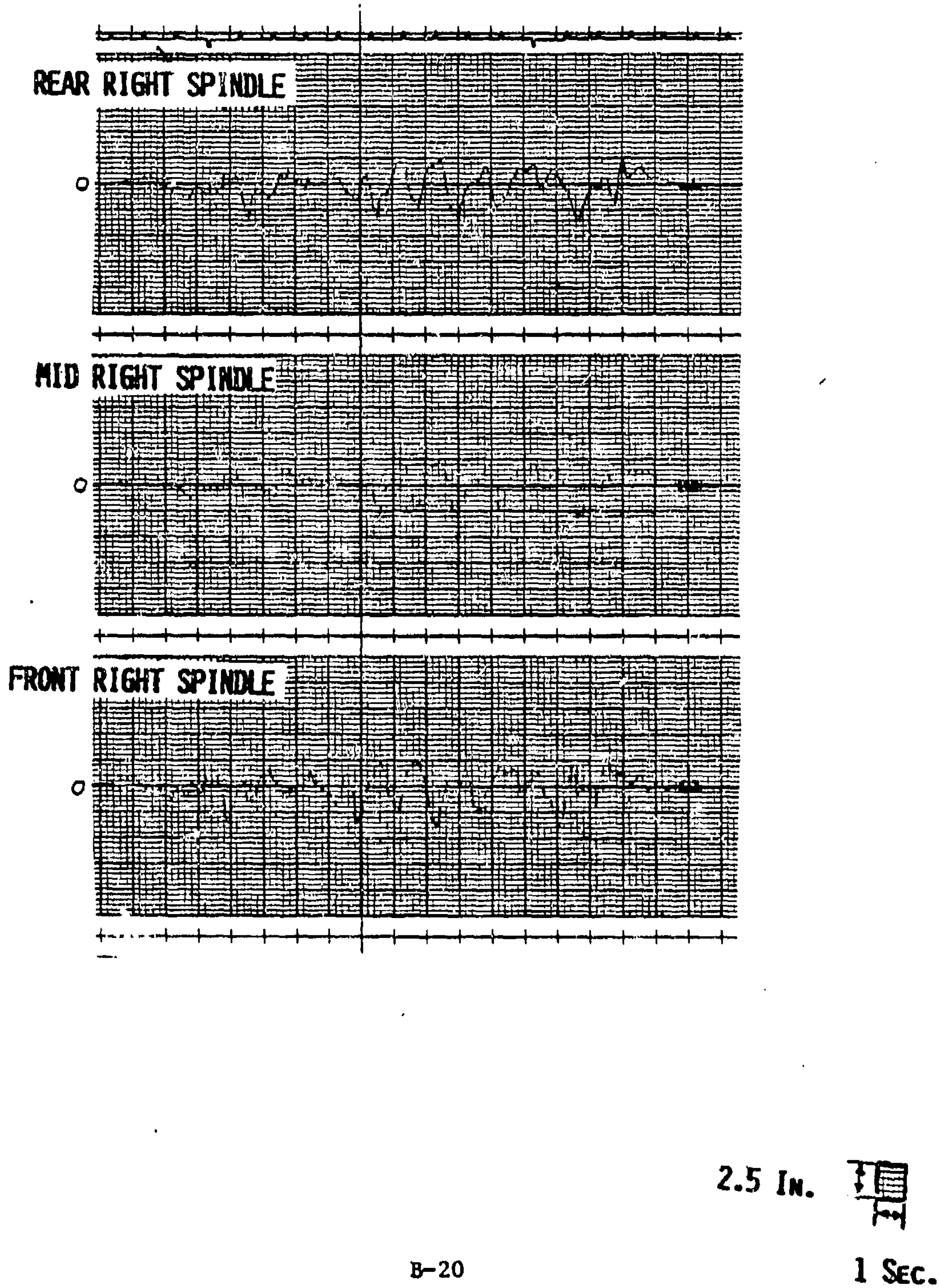
MEASURED ACTUATOR
POSITION RESPONSE

25 MPH APG37



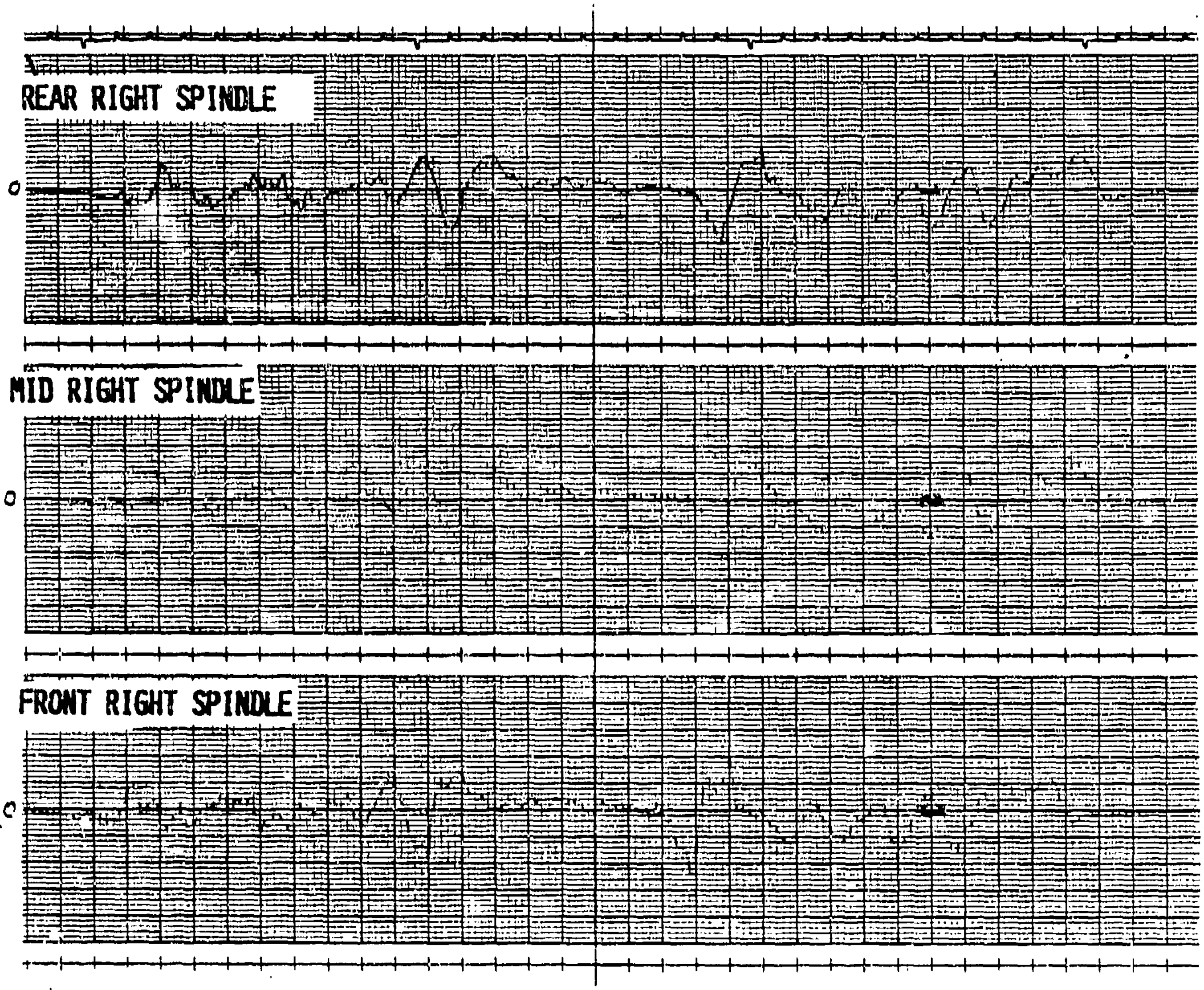
MEASURED ACTUATOR
POSITION RESPONSE

14 MPH APG9



MEASURED ACTUATOR
POSITION RESPONSE

9.3 MPH APG11

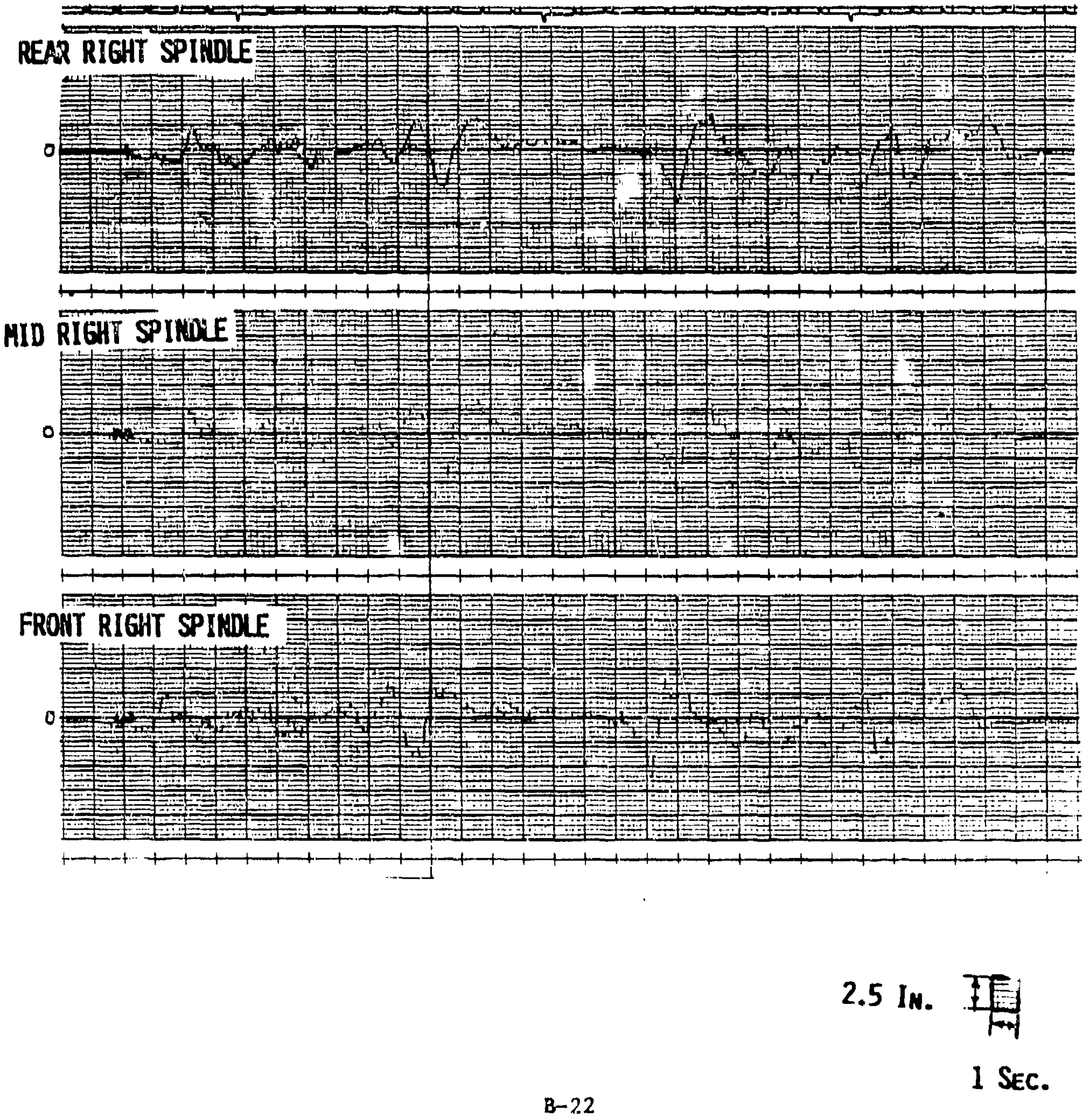


2.5 IN.

1 SEC.

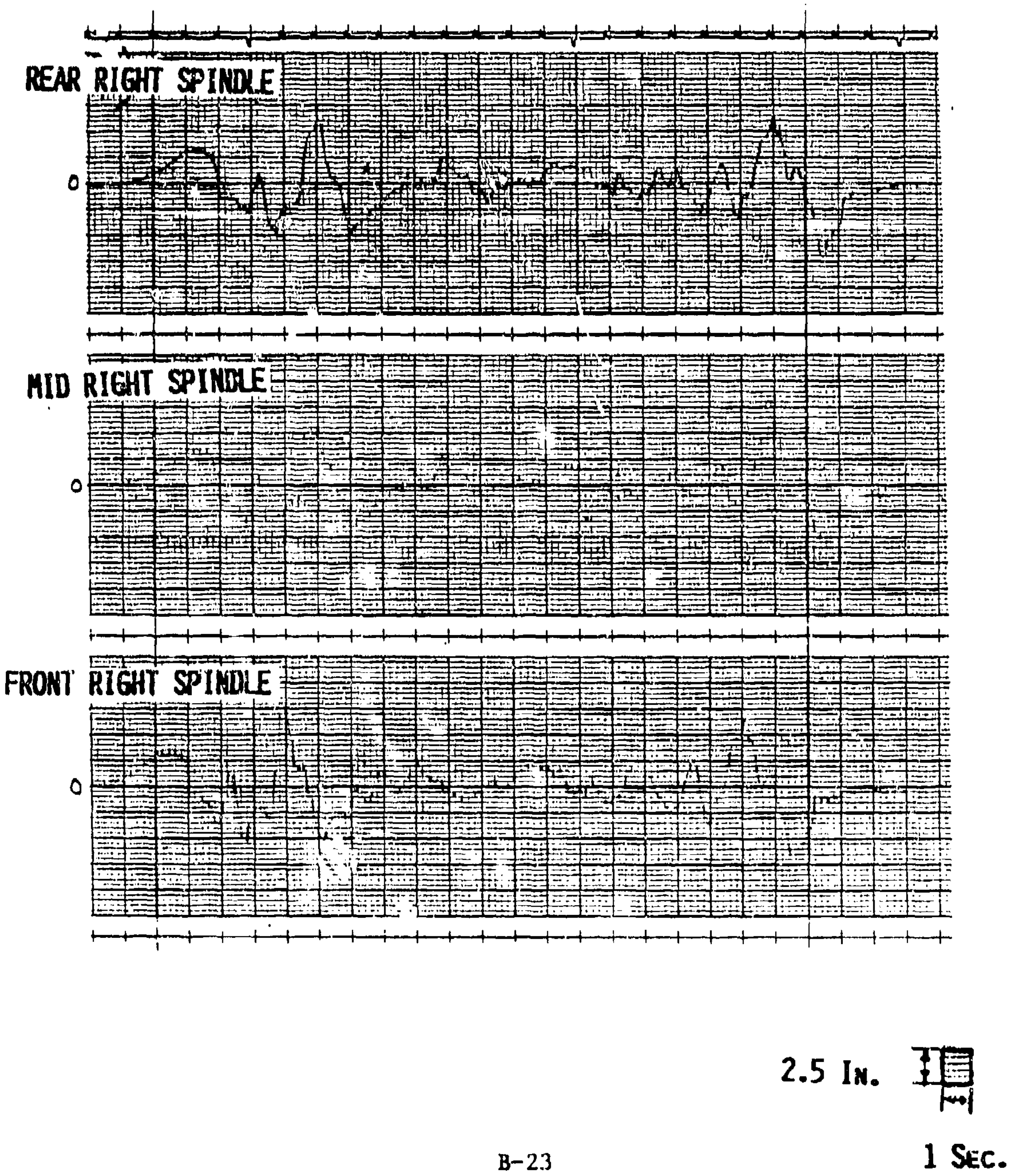
MEASURED ACTUATOR
POSITION RESPONSE

9.8 MPH APG11



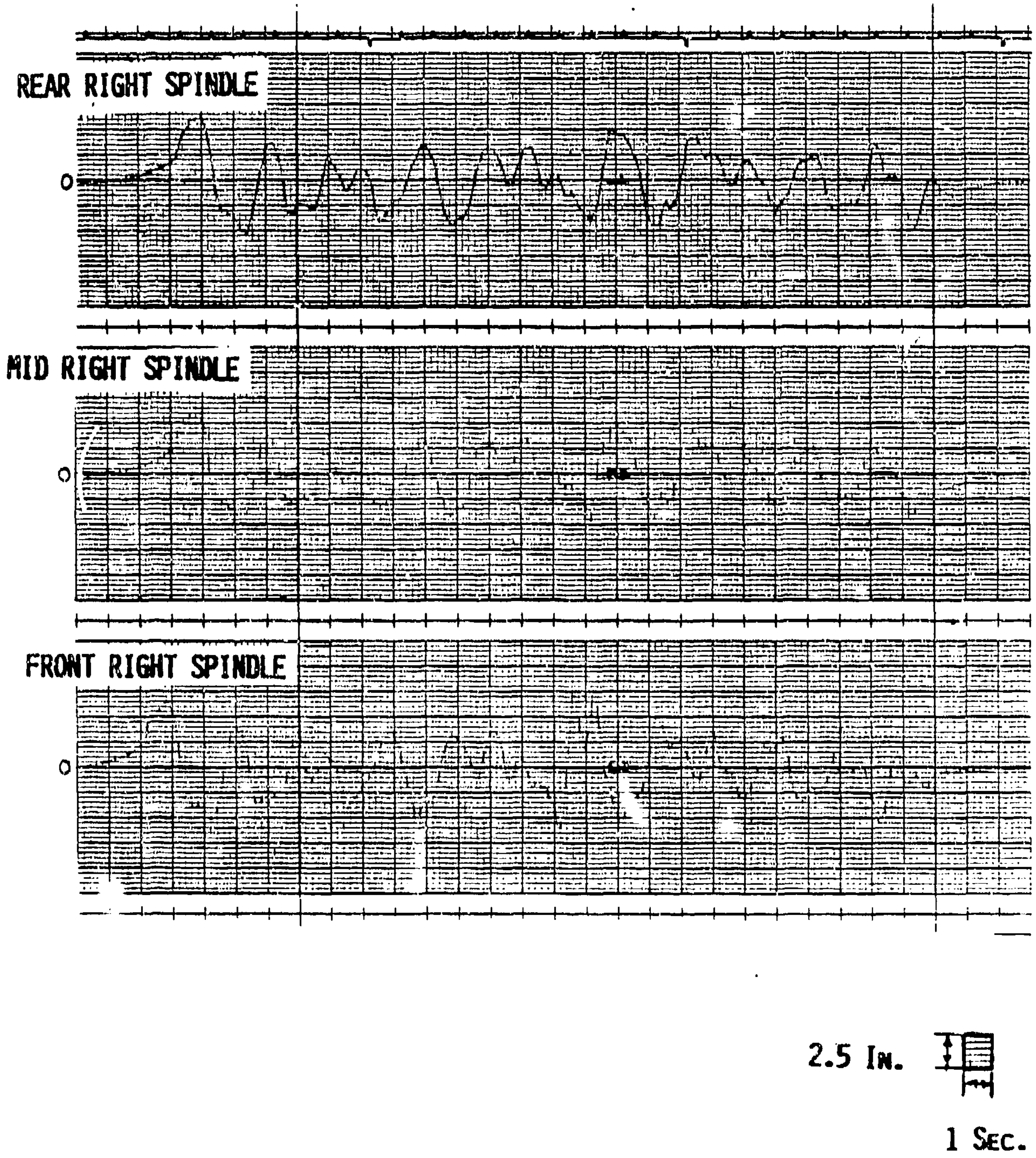
MEASURED ACTUATOR
POSITION RESPONSE

10 MPH APG12



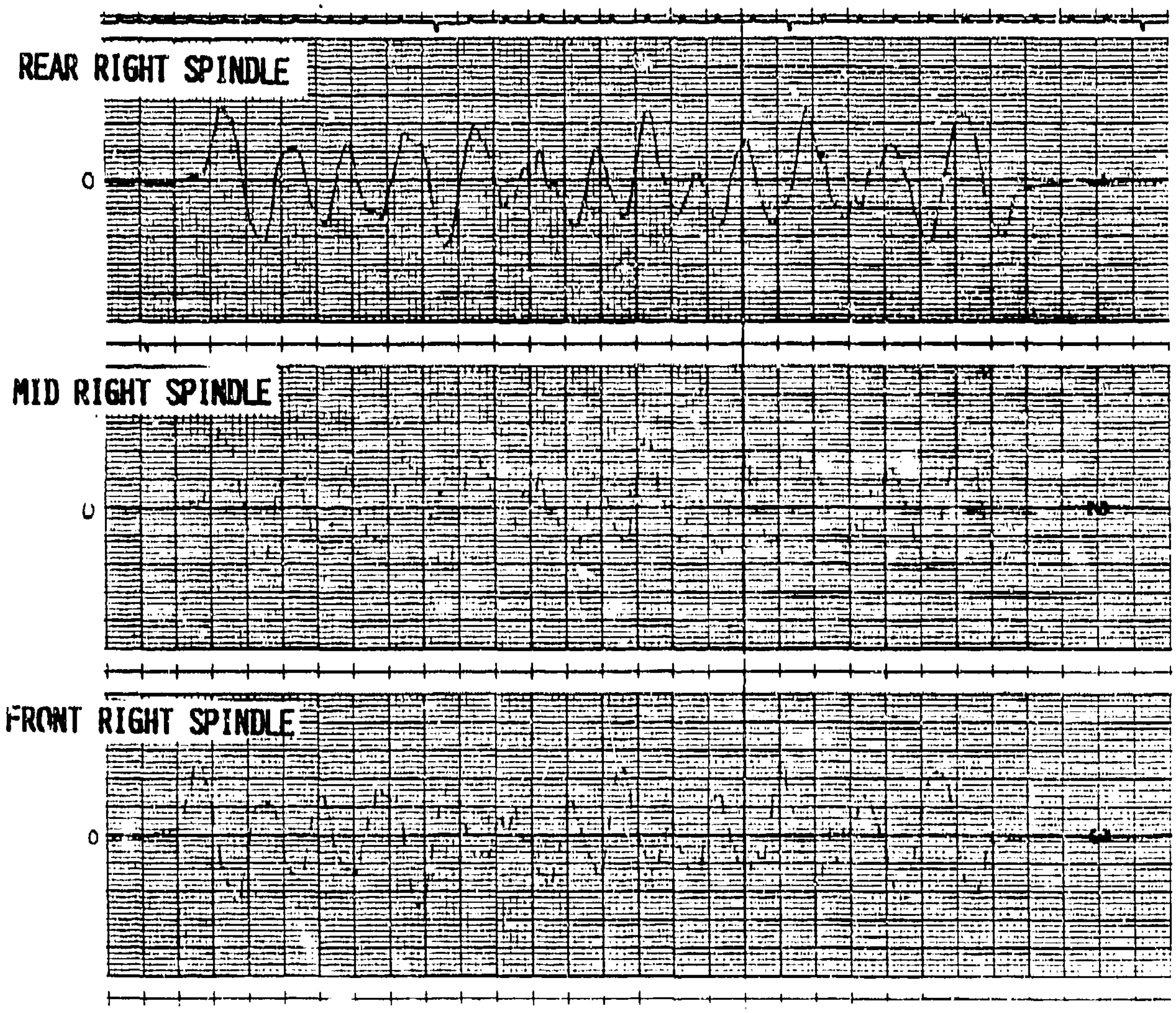
MEASURED ACTUATOR
POSITION RESPONSE

8.5 MPH APG29



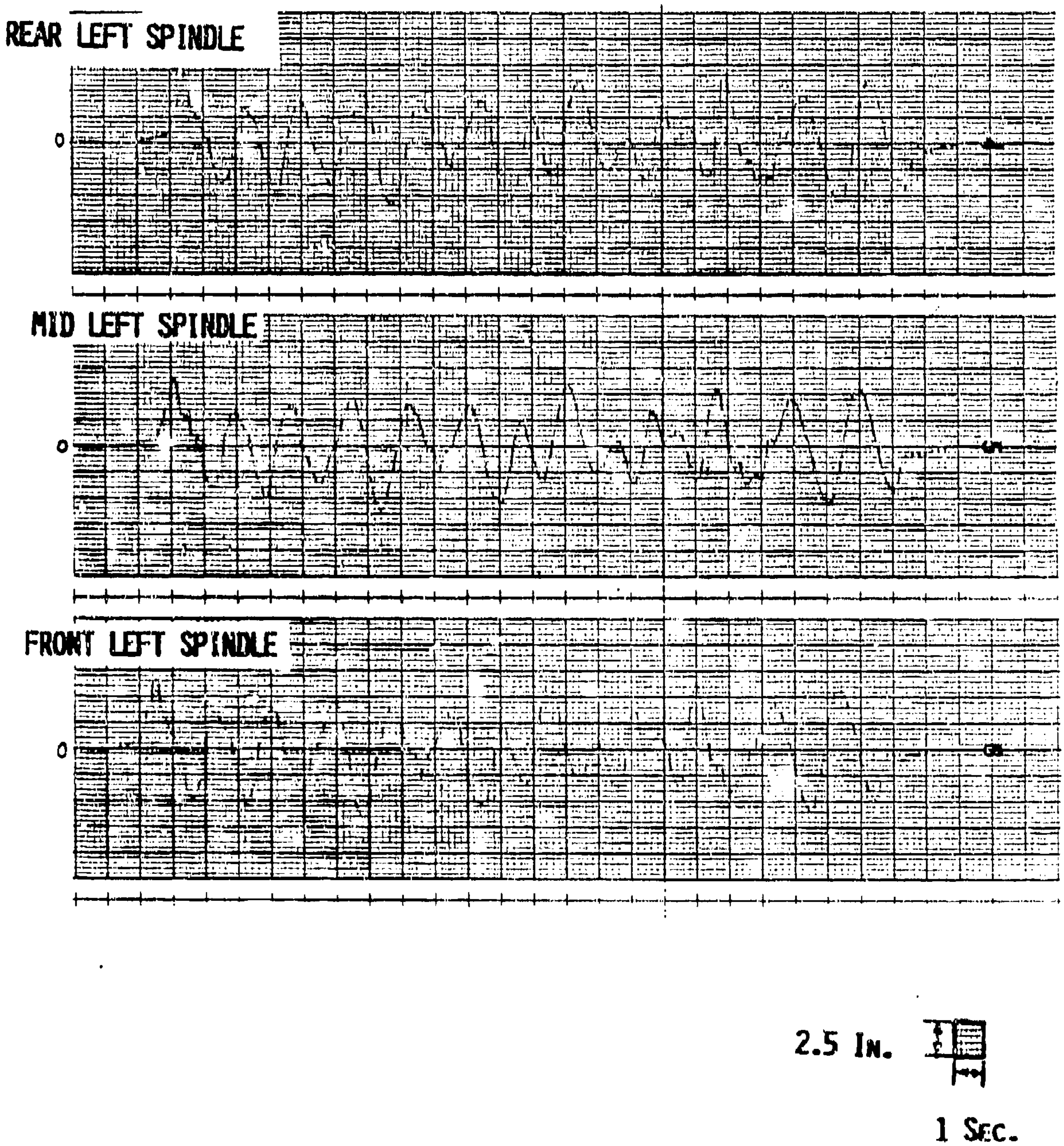
MEASURED ACTUATOR
POSITION RESPONSE

12 MPH FORT KNOX 910



MEASURED ACTUATOR
POSITION RESPONSE

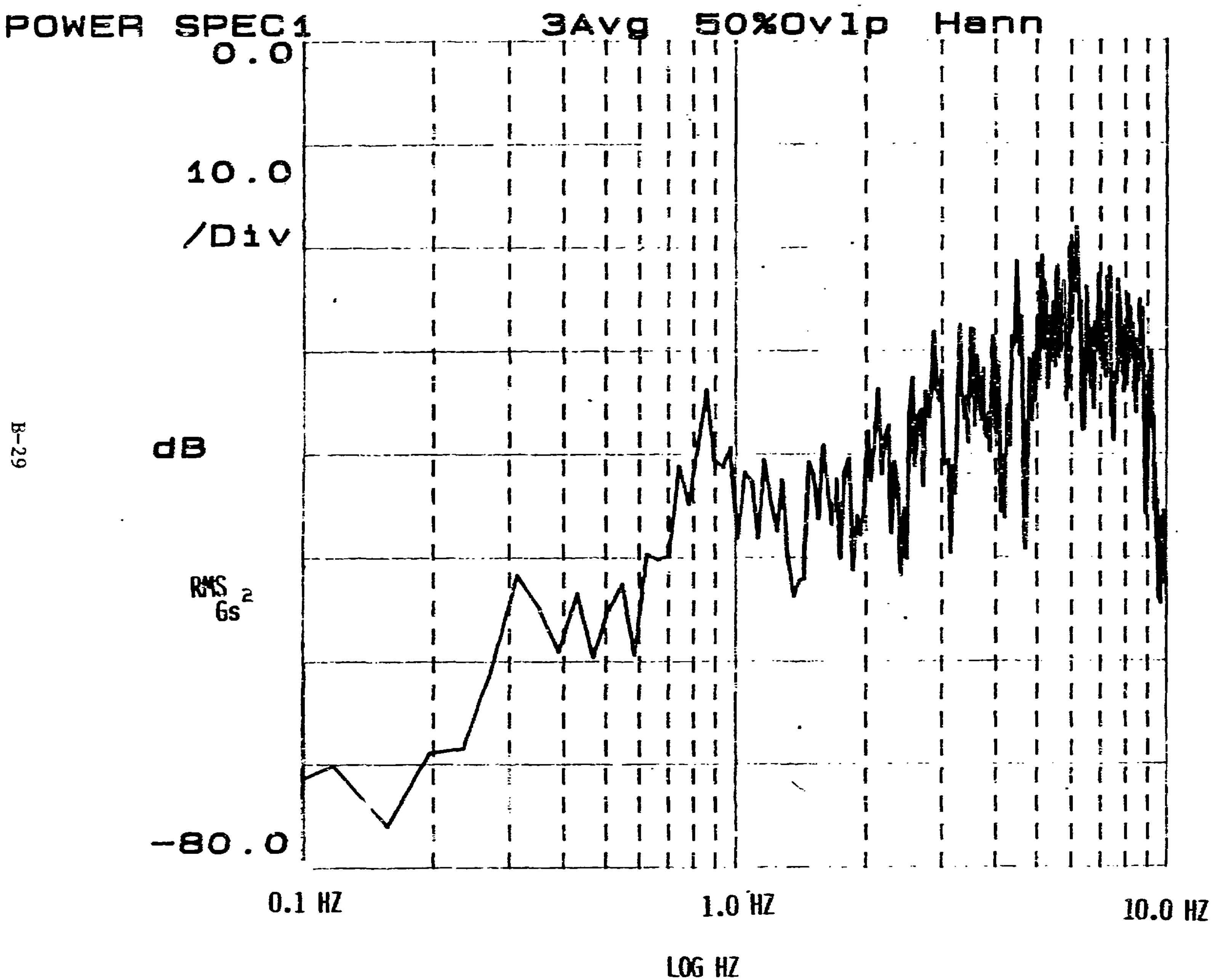
12 MPH FORT KNOX 910



POWER SPECTRUMS

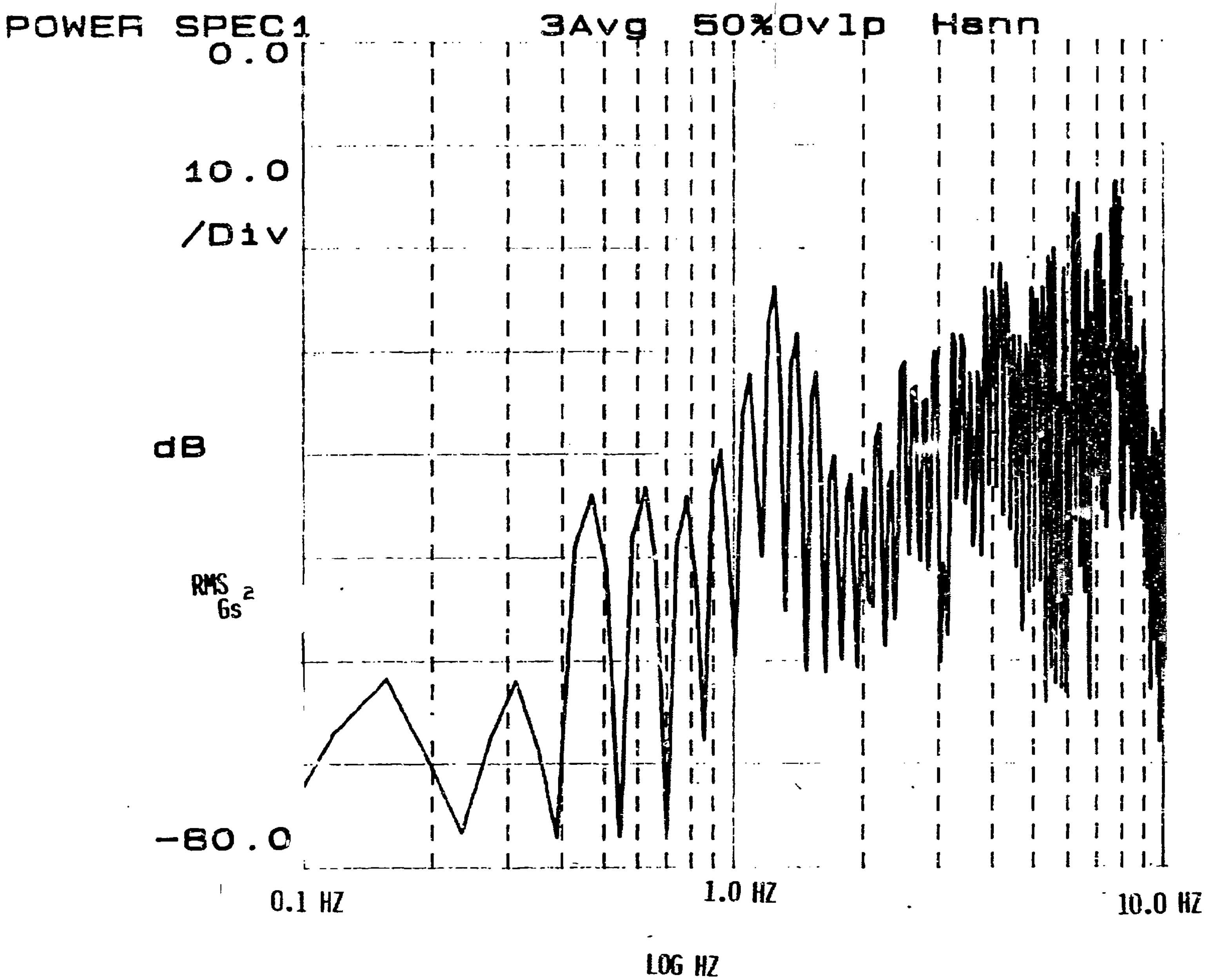
FRONT LEFT SPINDLE ACCELERATION

MEASURED POWER SPECTRAL ANALYSIS 30 MPH CHV1
FRONT LEFT SPINDLE ACCELERATION

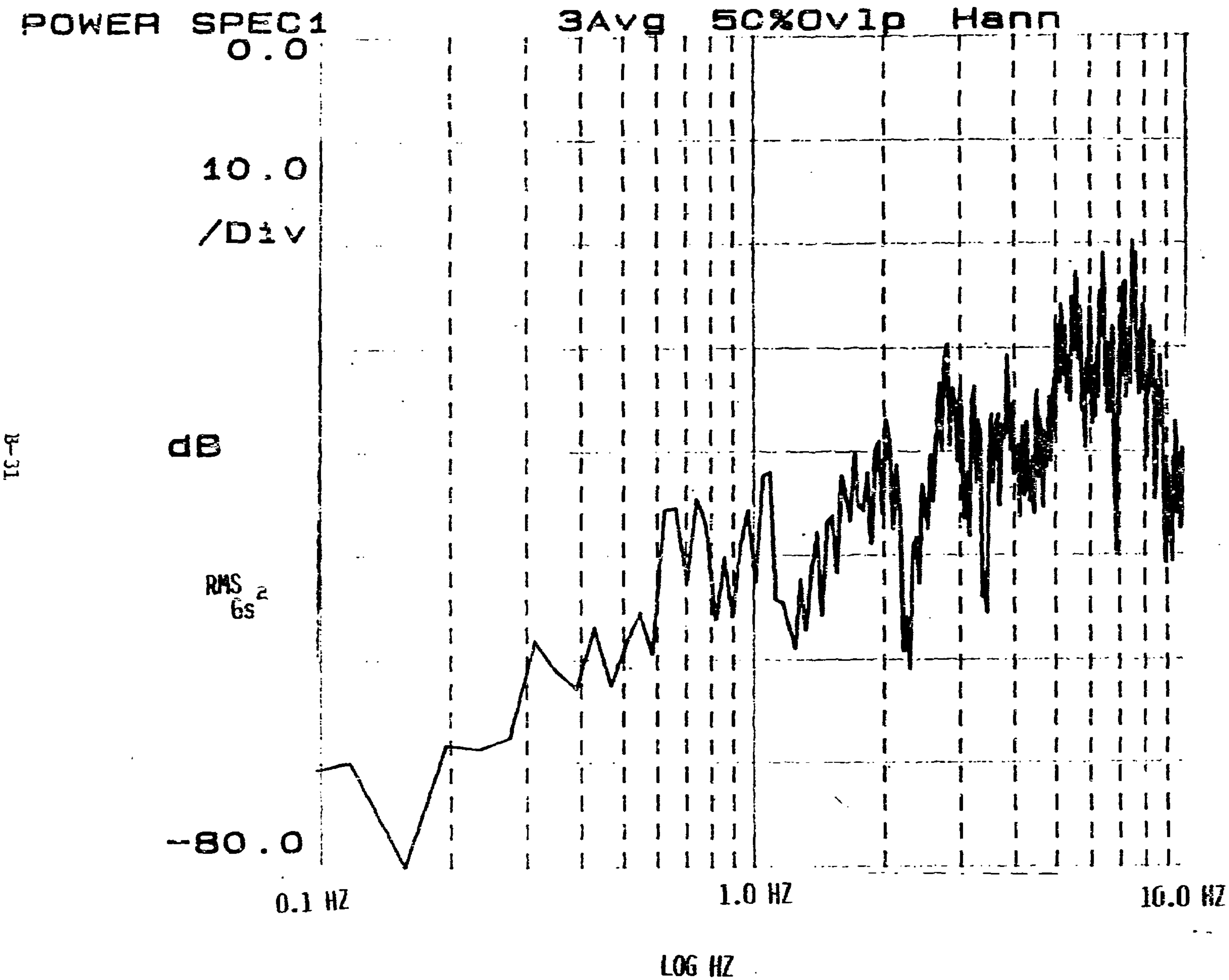


MEASURED POWER SPECTRAL ANALYSIS
FRONT LEFT SPINDLE ACCELERATION

45 MPH CHV1

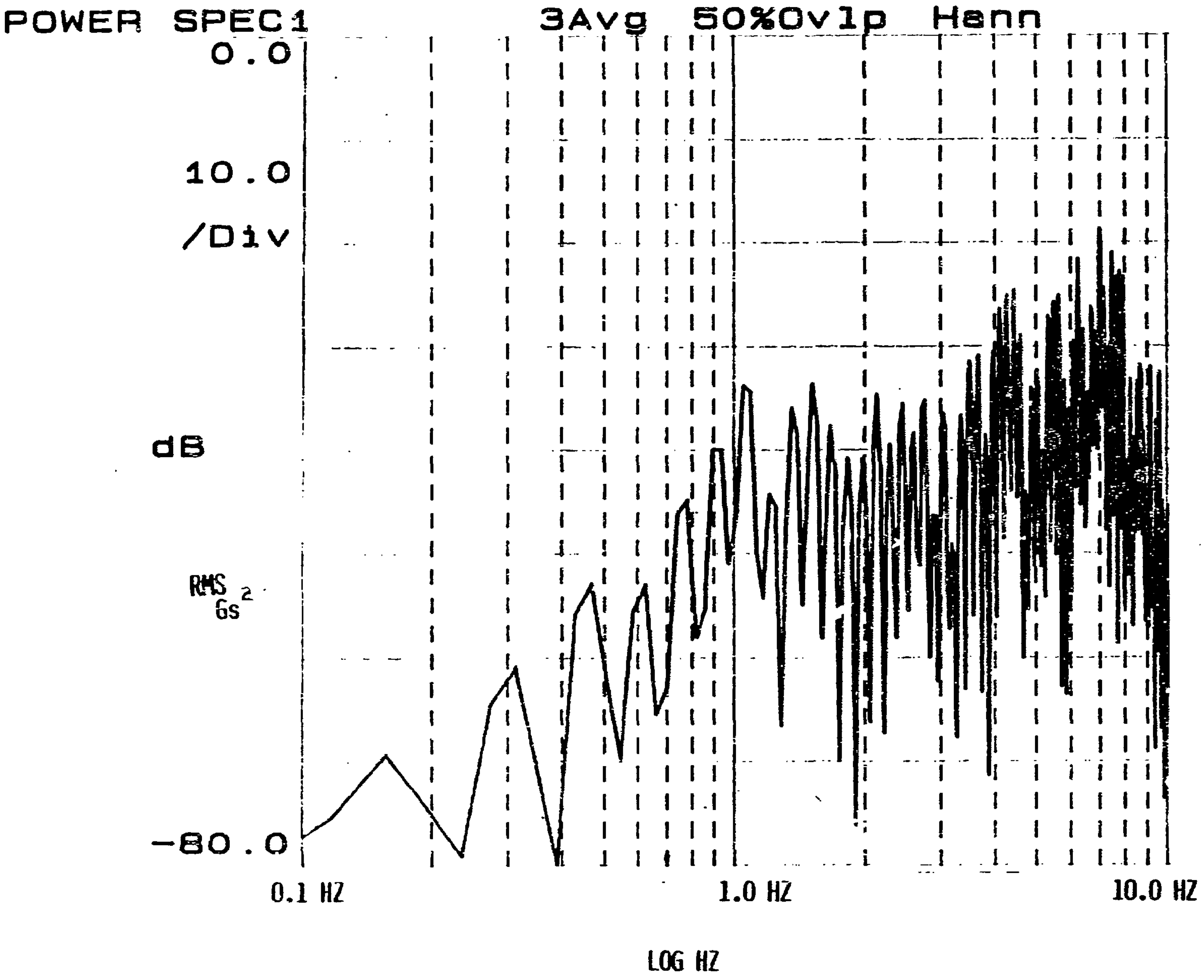


MEASURED POWER SPECTRAL ANALYSIS 30 MPH CHV6
FRONT LEFT SPINDLE ACCELERATION



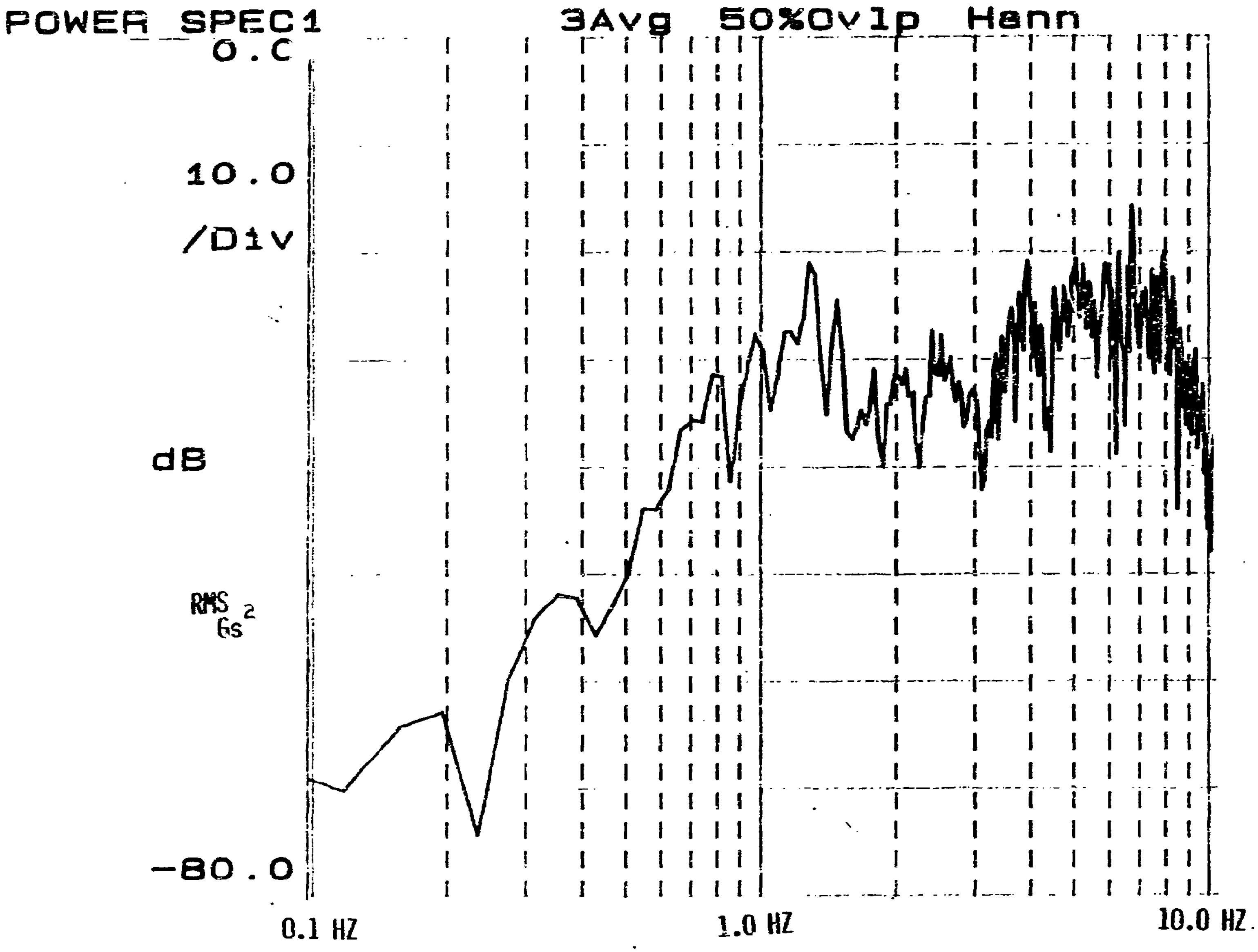
MEASURED POWER SPECTRAL ANALYSIS
FRONT LEFT SPINDLE ACCELERATION

45 MPH CHV6

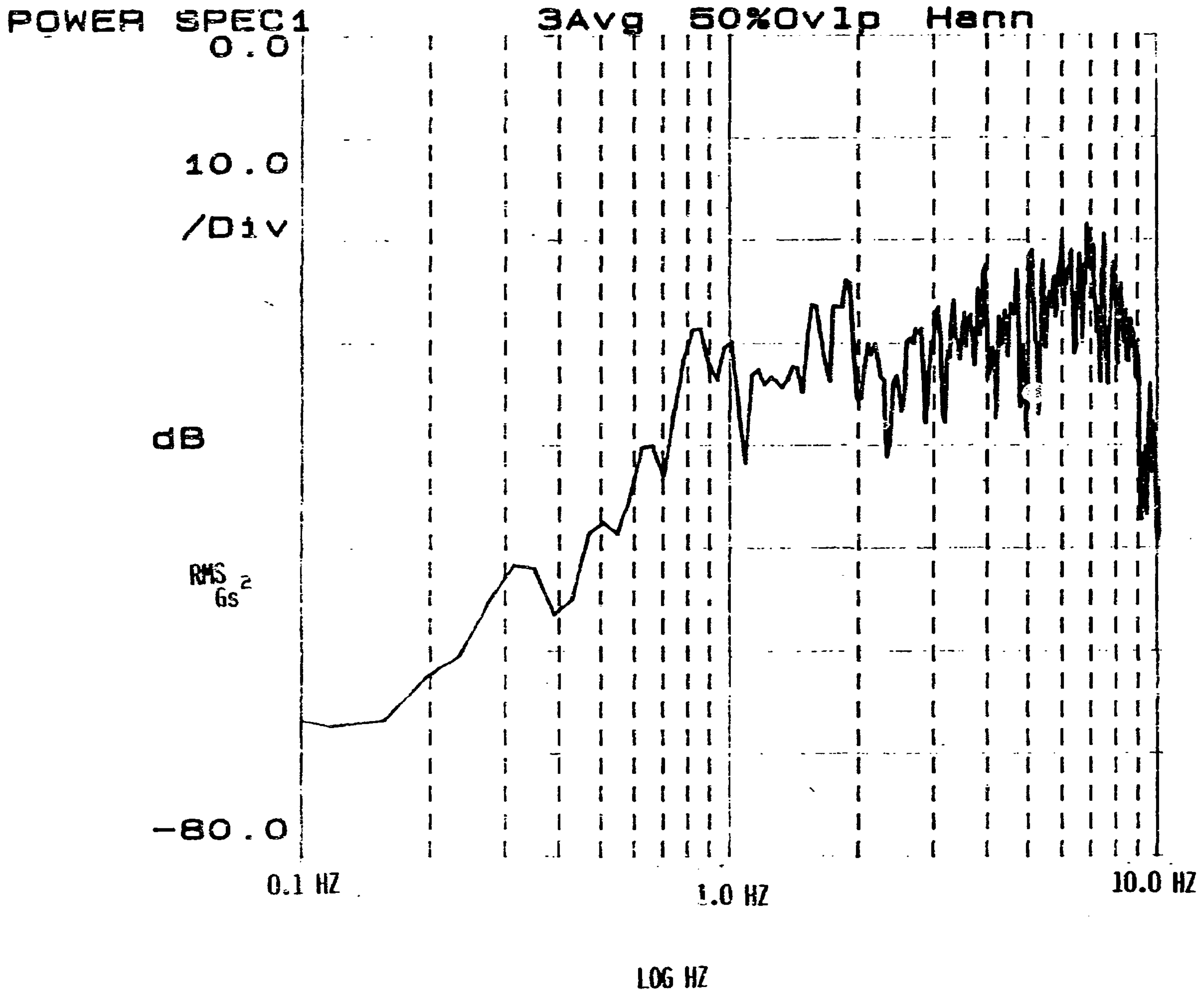


MEASURED POWER SPECTRAL ANALYSIS
FRONT LEFT SPINDLE ACCELERATION

25 MPH APG37

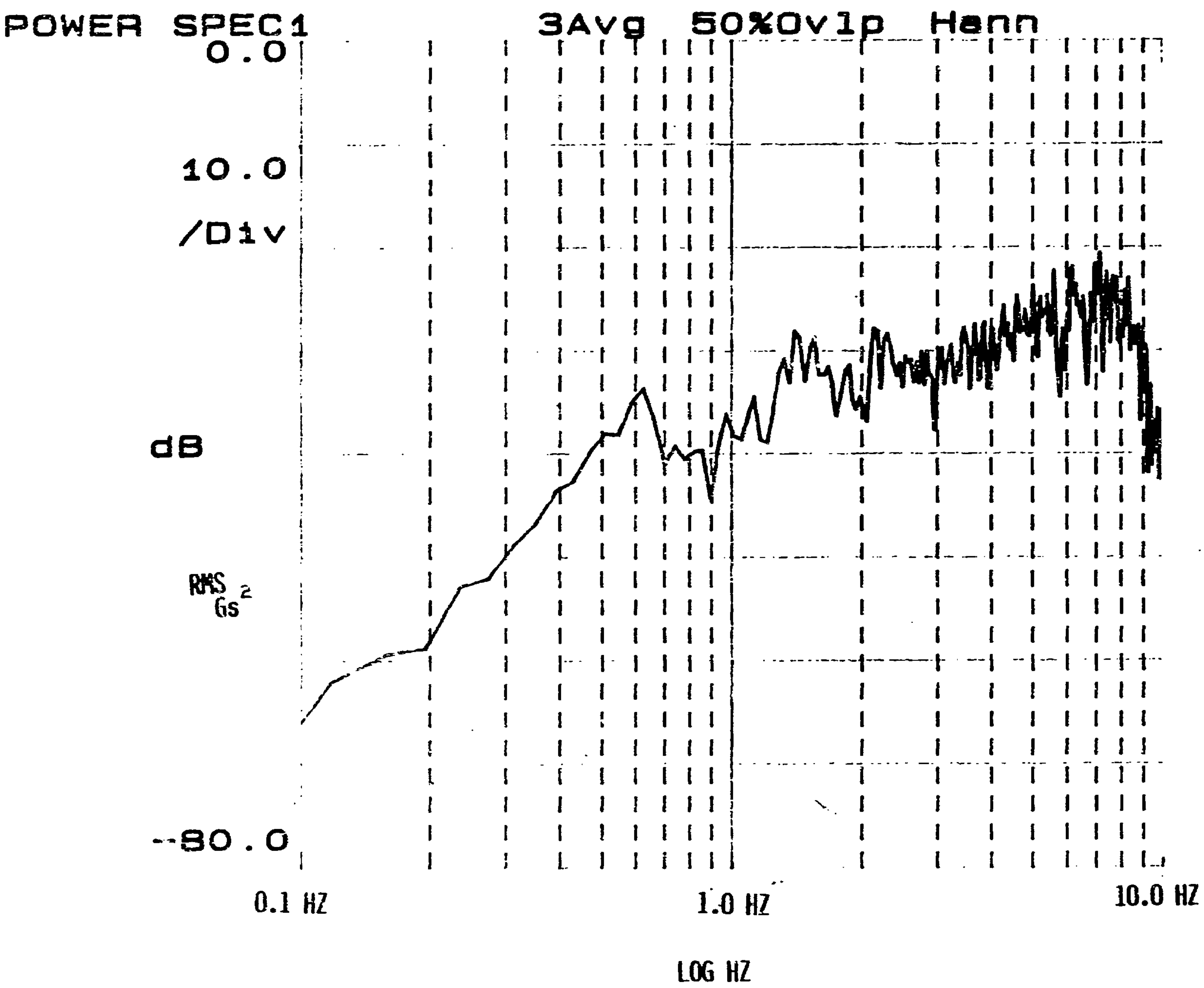


MEASURED POWER SPECTRAL ANALYSIS 14 MPH APG9
FRONT LEFT SPINDLE ACCELERATION



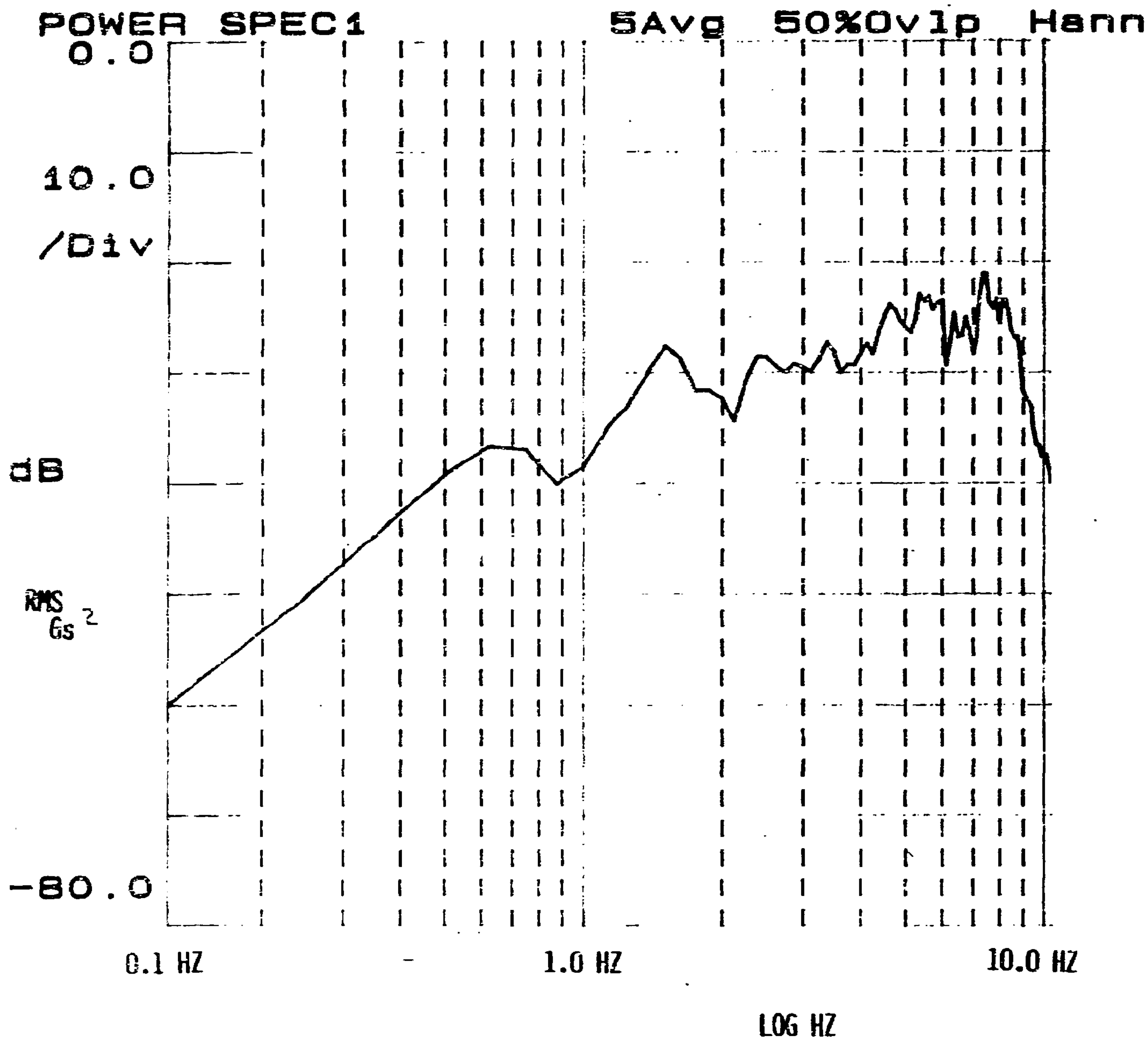
MEASURED POWER SPECTRAL ANALYSIS
FRONT LEFT SPINDLE ACCELERATION

9.3 MPH APG11



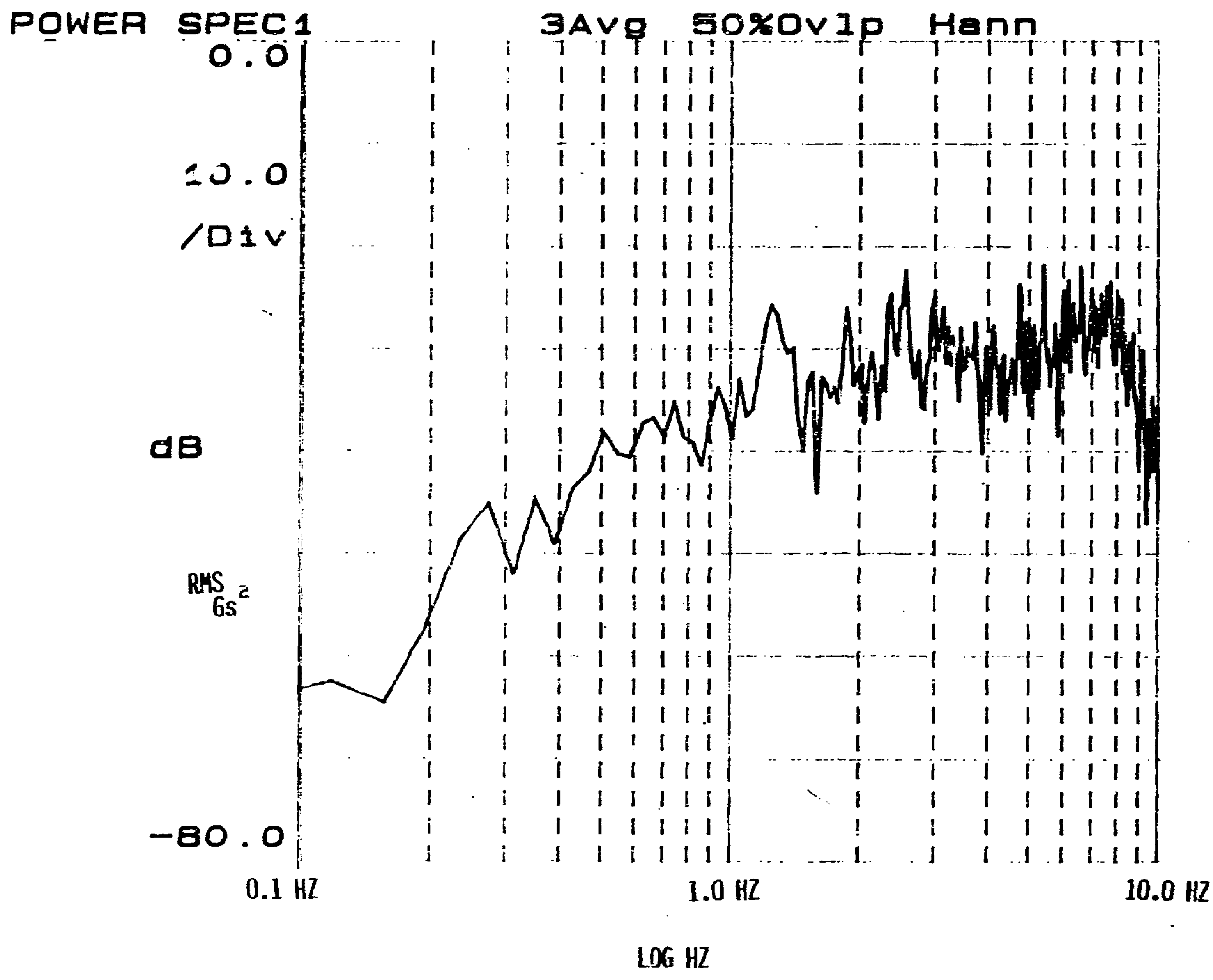
MEASURED POWER SPECTRAL ANALYSIS
FRONT LEFT SPINDLE ACCELERATION

9.8 MPH AP612



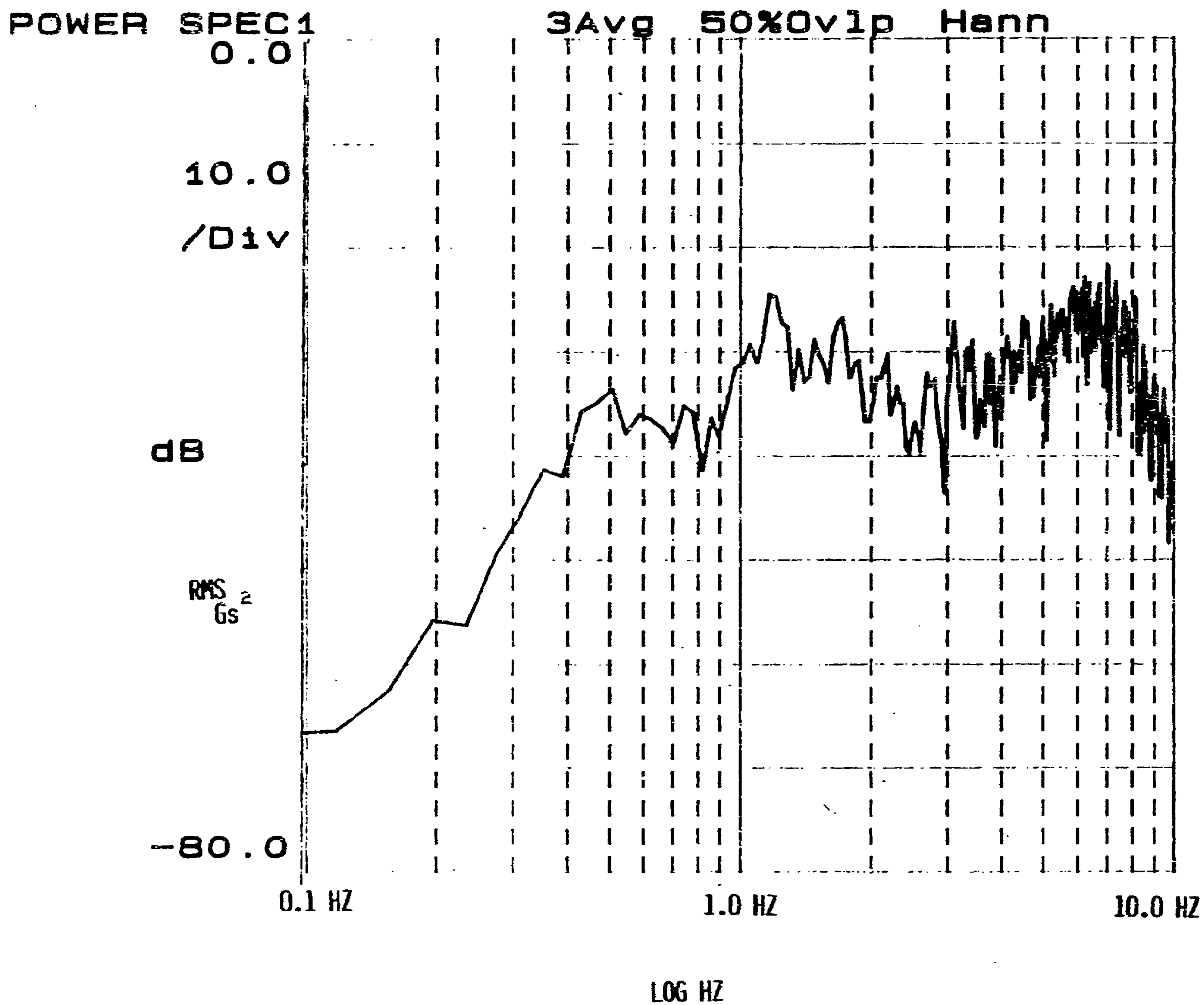
MEASURED POWER SPECTRAL ANALYSIS
FRONT LEFT SPINDLE ACCELERATION

10 MPH APG12



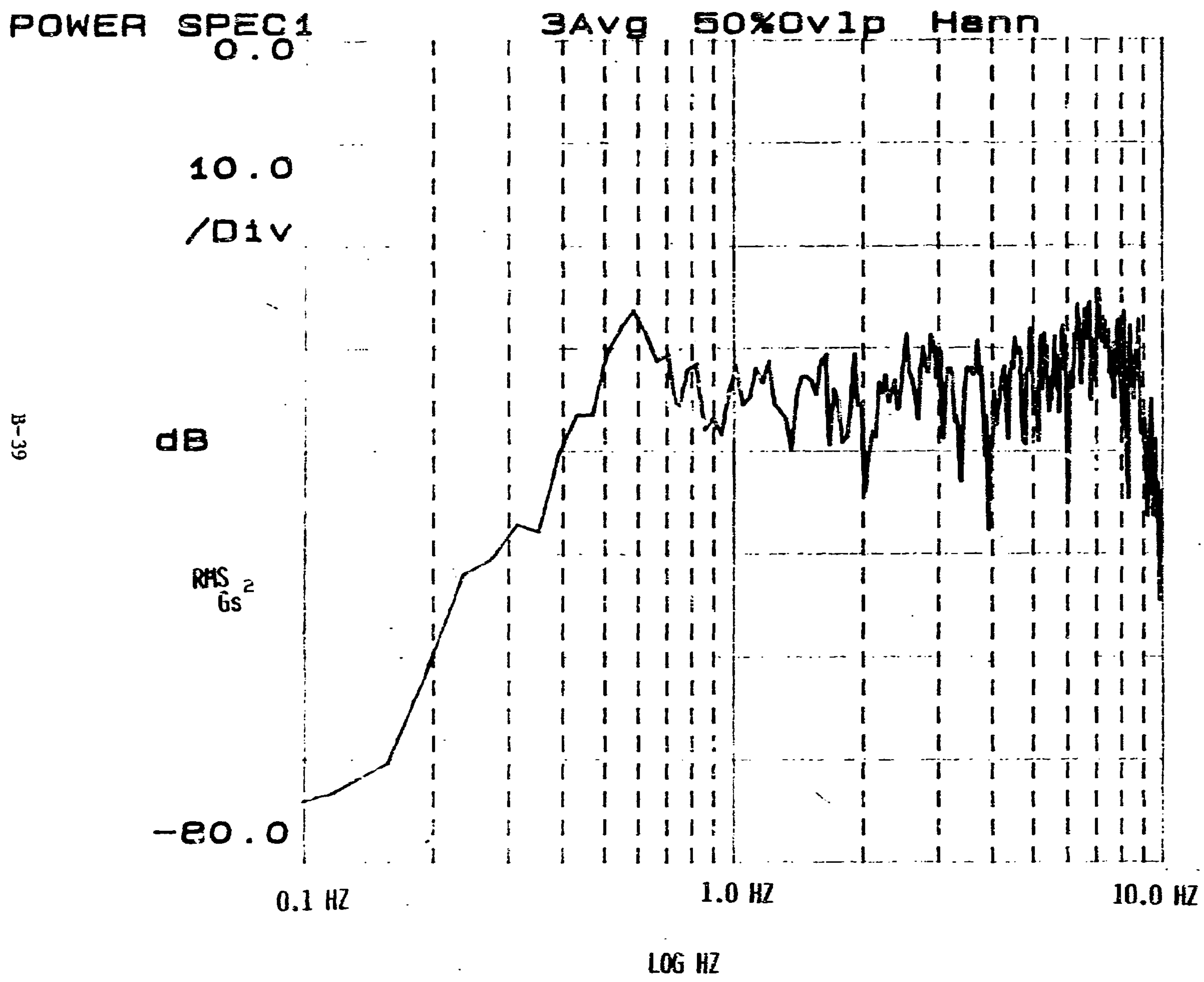
MEASURED POWER SPECTRAL ANALYSIS
FRONT LEFT SPINDLE ACCELERATION

8.5 MPH AP629



MEASURED POWER SPECTRAL ANALYSIS
FRONT LEFT SPINDLE ACCELERATION

12 MPH FORT KNOX 910

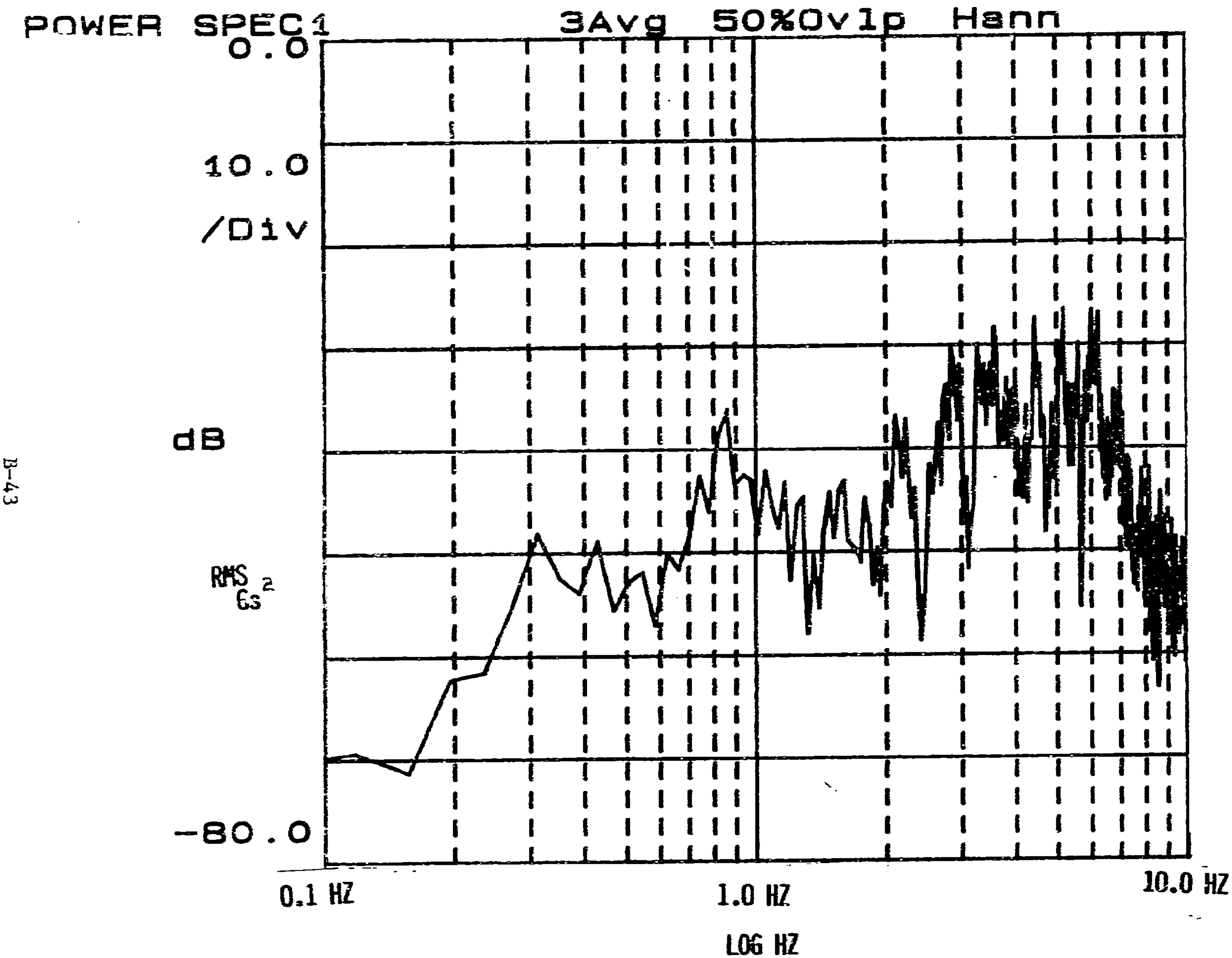


MEASURED POWER SPECTRUMS

VERTICAL SEAT ACCELERATION

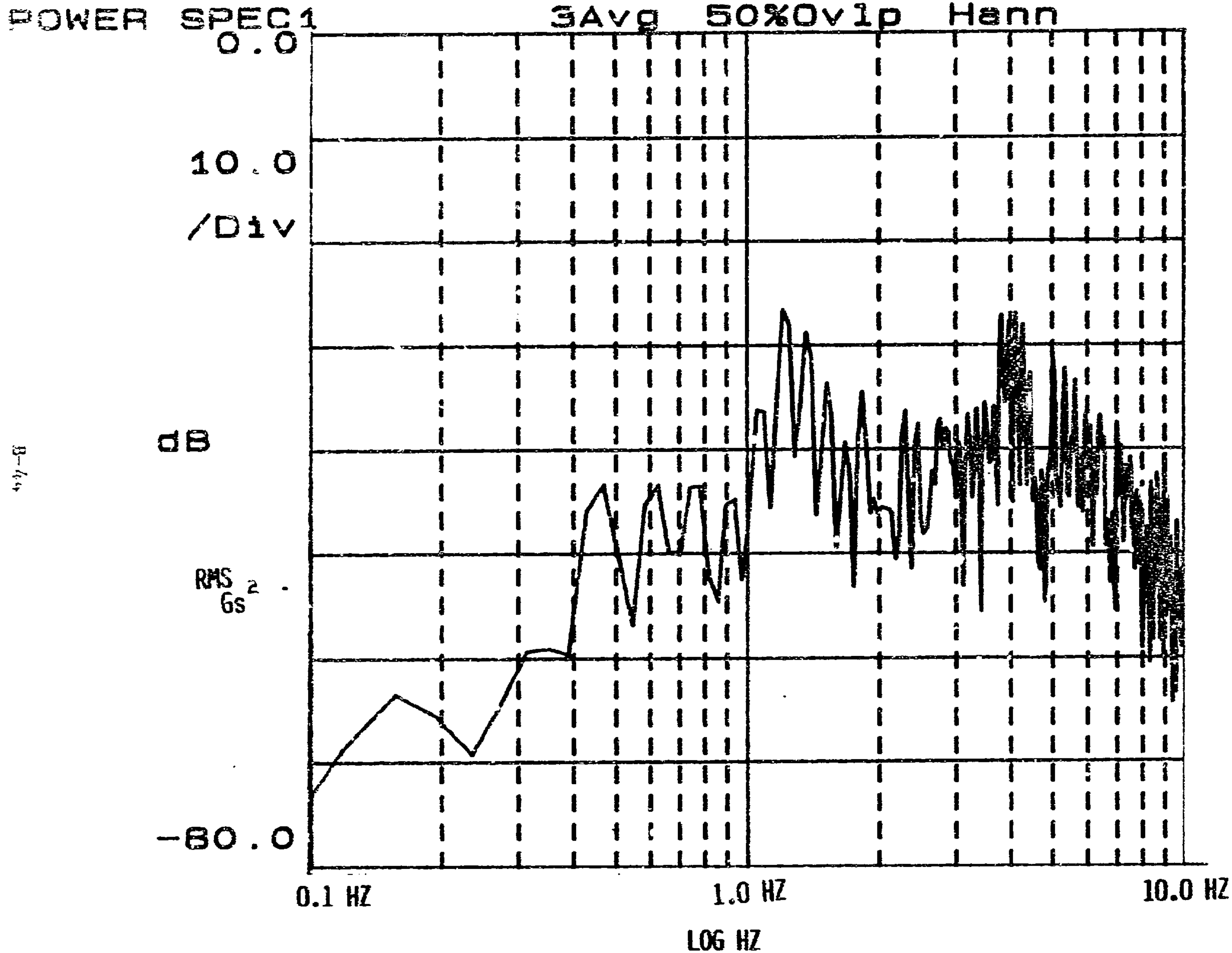
MEASURED POWER SPECTRAL ANALYSIS
VERTICAL SEAT ACCELERATION

30 MPH CHV1



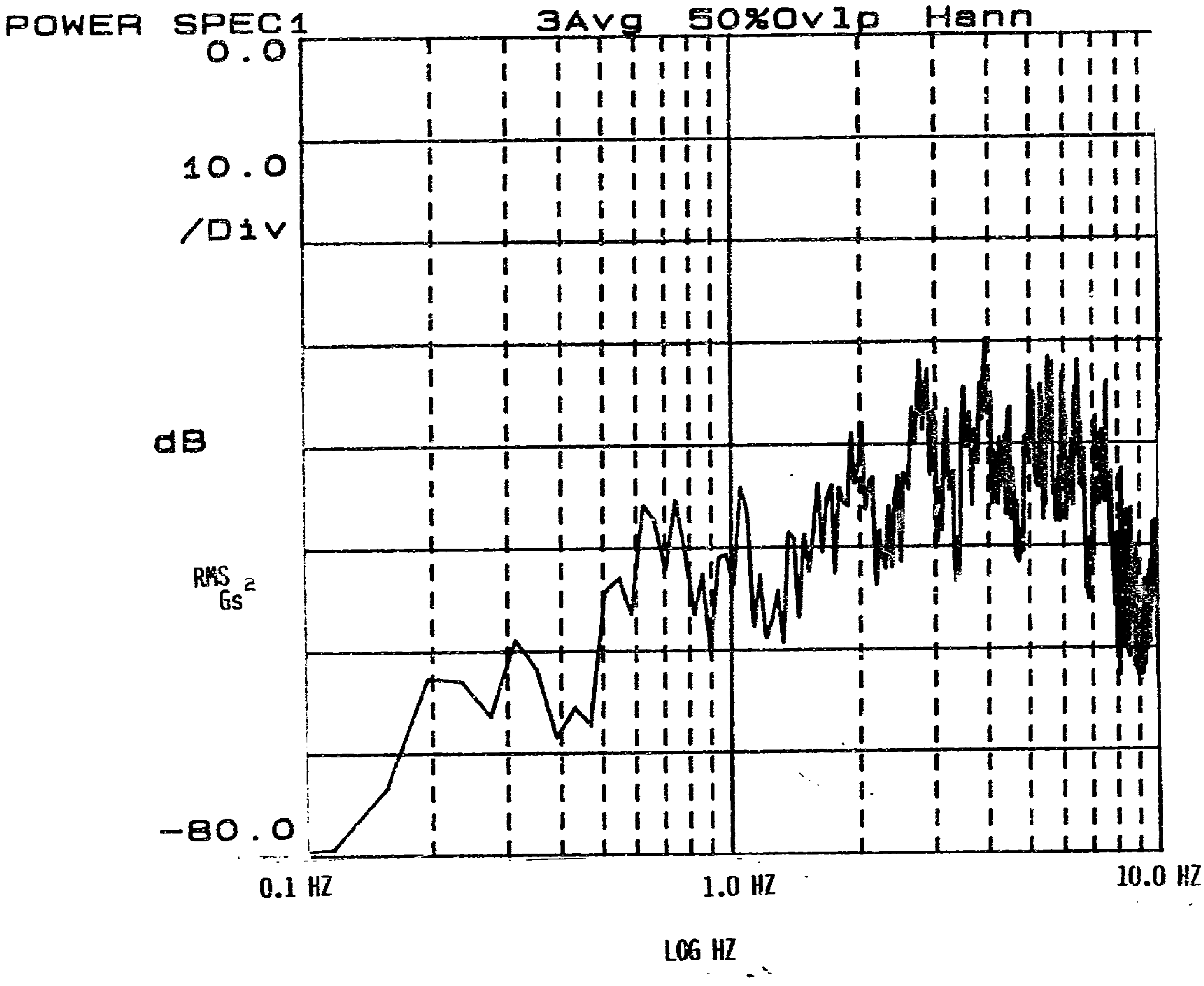
MEASURED POWER SPECTRAL ANALYSIS
VERTICAL SEAT ACCELERATION

45 MPH CHV1



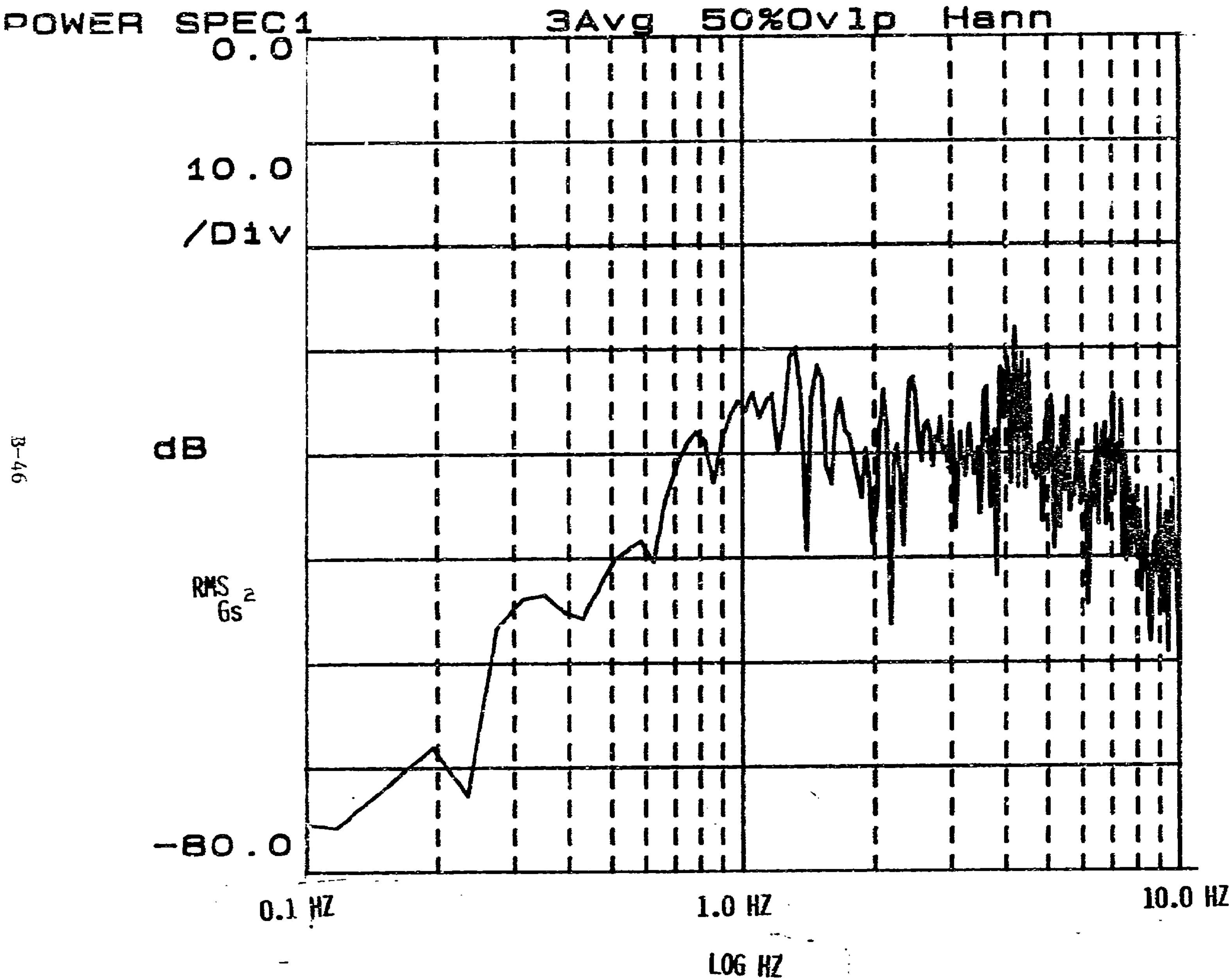
MEASURED POWER SPECTRAL ANALYSIS
VERTICAL SEAT ACCELERATION

30 MPH CHV6



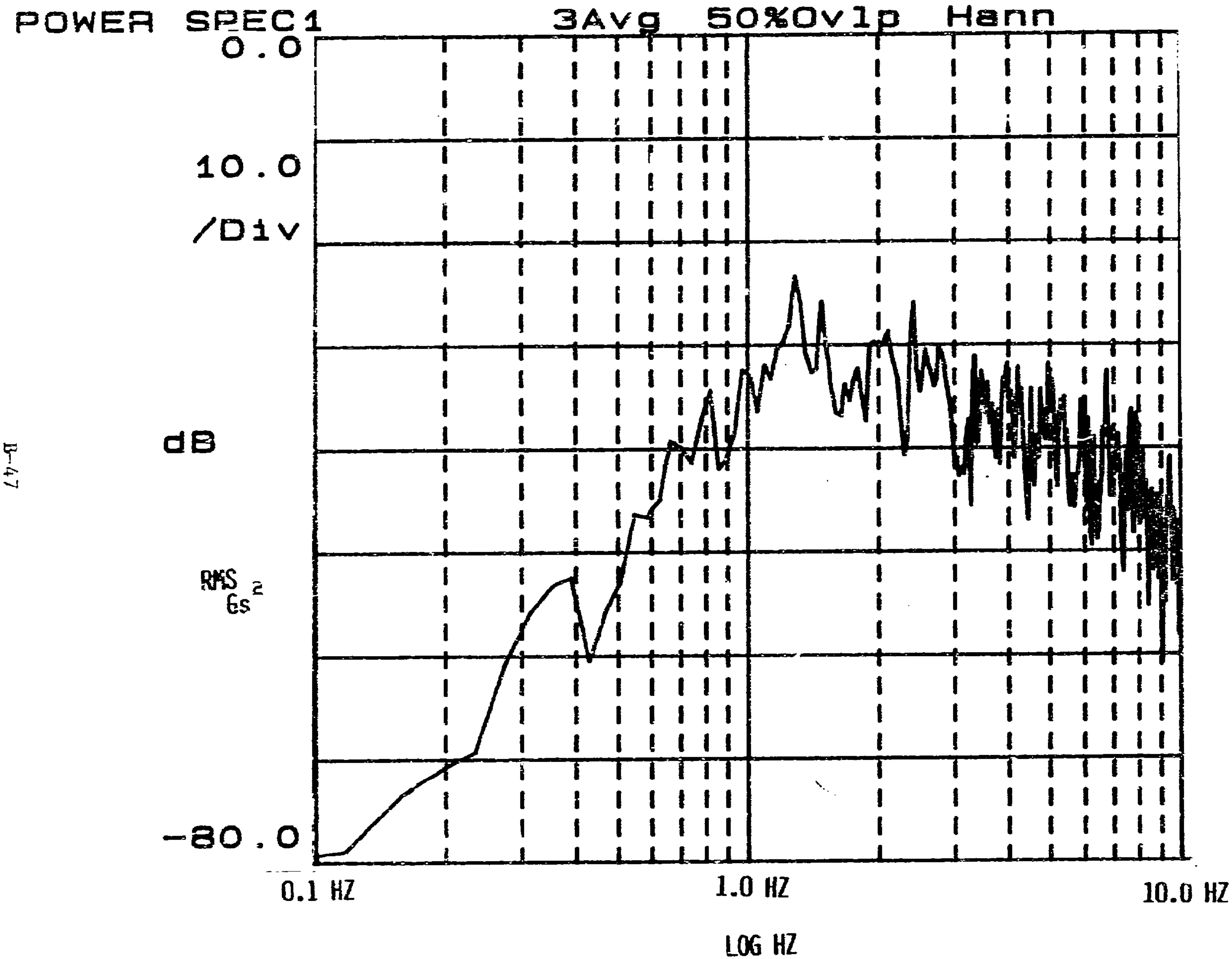
MEASURED POWER SPECTRAL ANALYSIS
VERTICAL SEAT ACCELERATION

45 MPH CHV6



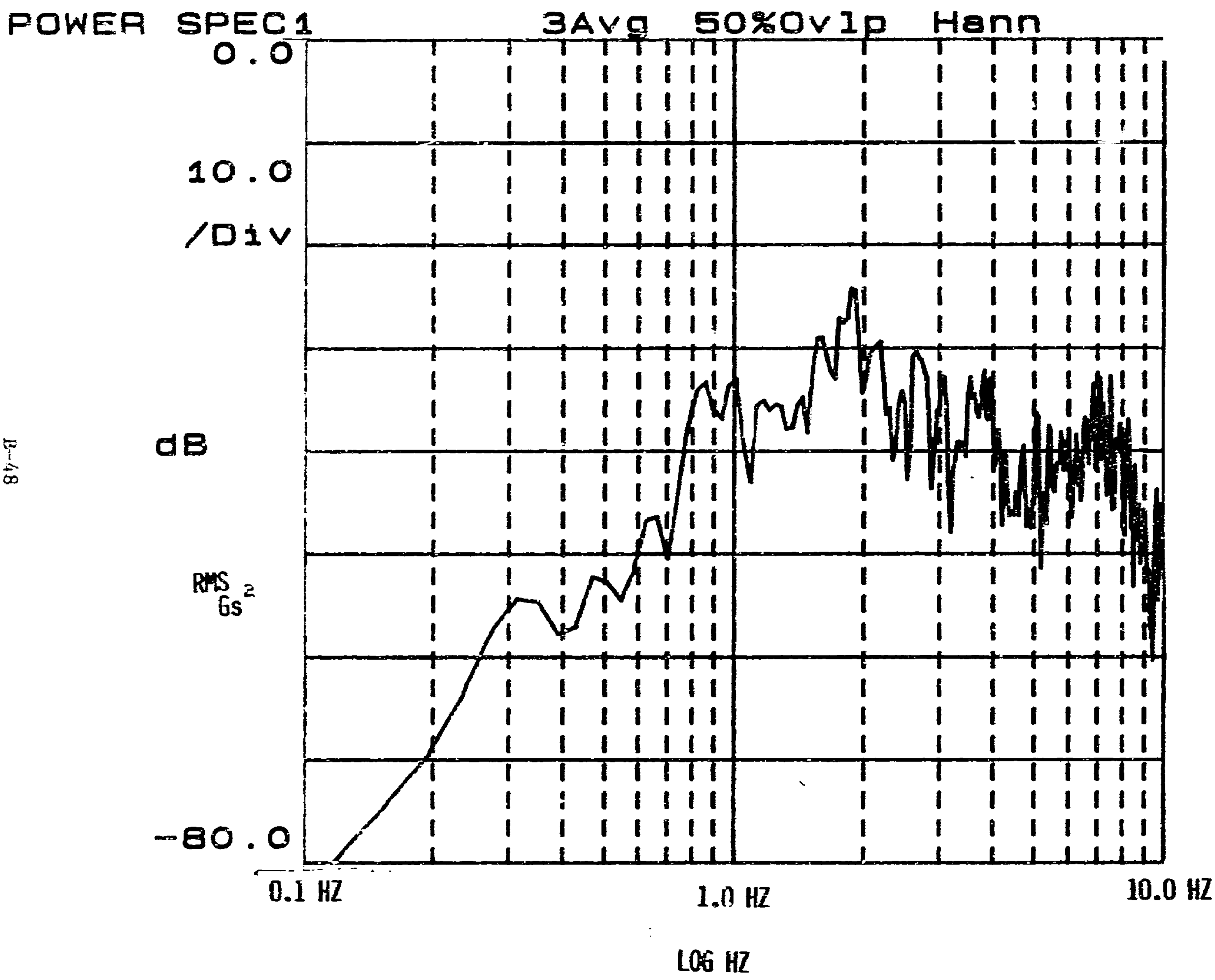
MEASURED POWER SPECTRAL ANALYSIS
VERTICAL SEAT ACCELERATION

25 MPH AP637

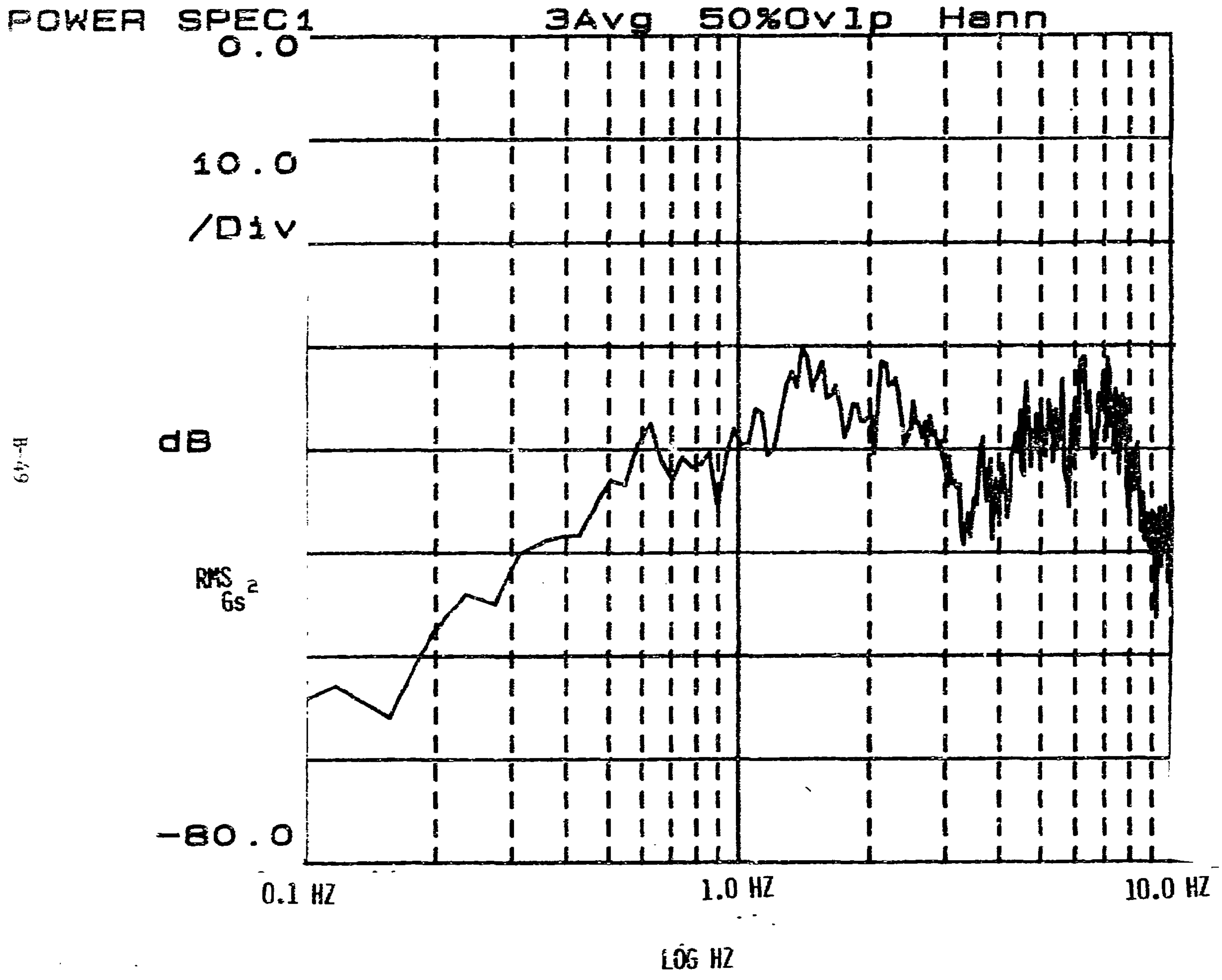


MEASURED POWER SPECTRAL ANALYSIS
VERTICAL SEAT ACCELERATION

14 MPH AP69

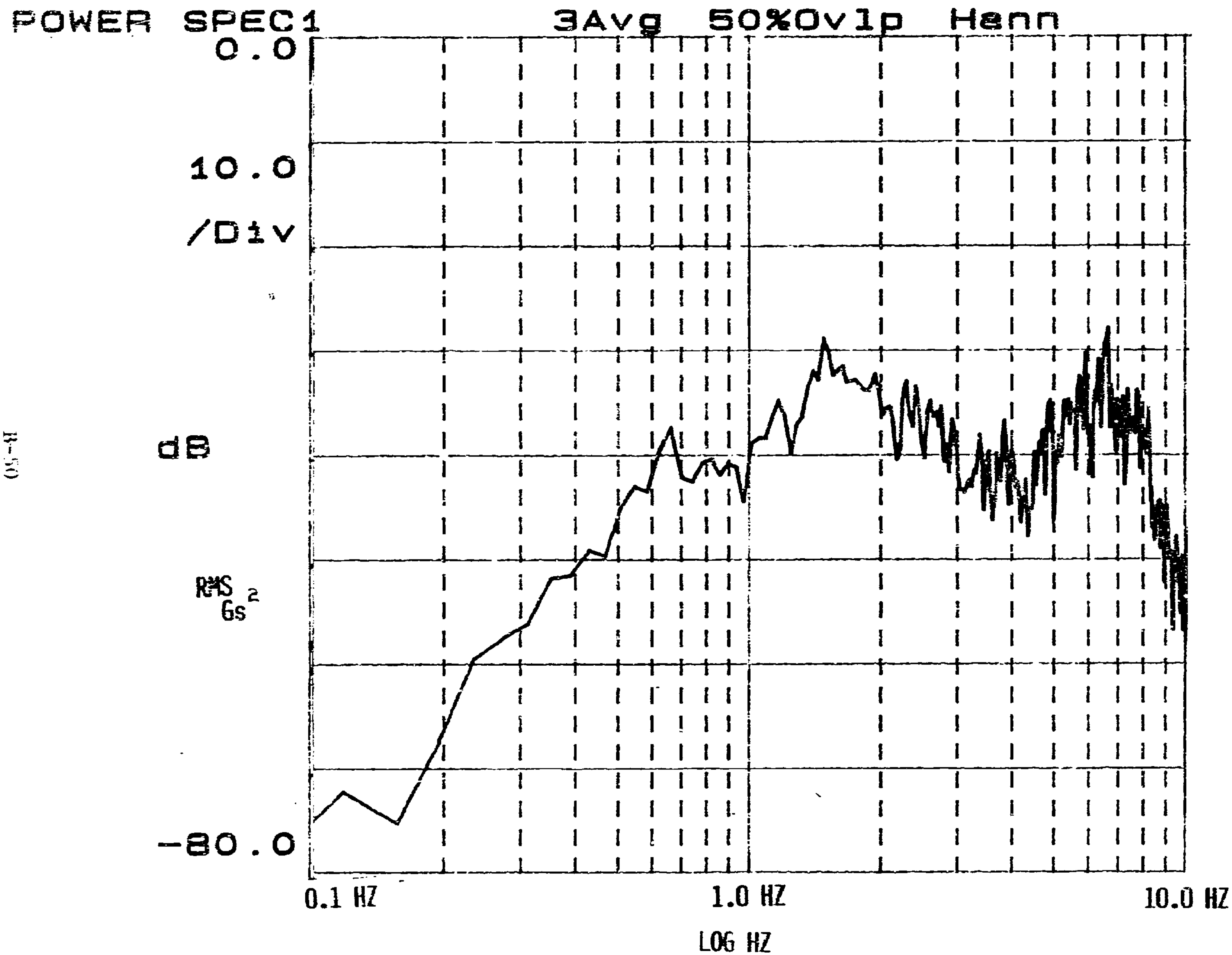


MEASURED POWER SPECTRAL ANALYSIS 9.3 MPH APG11
VERTICAL SEAT ACCELERATION



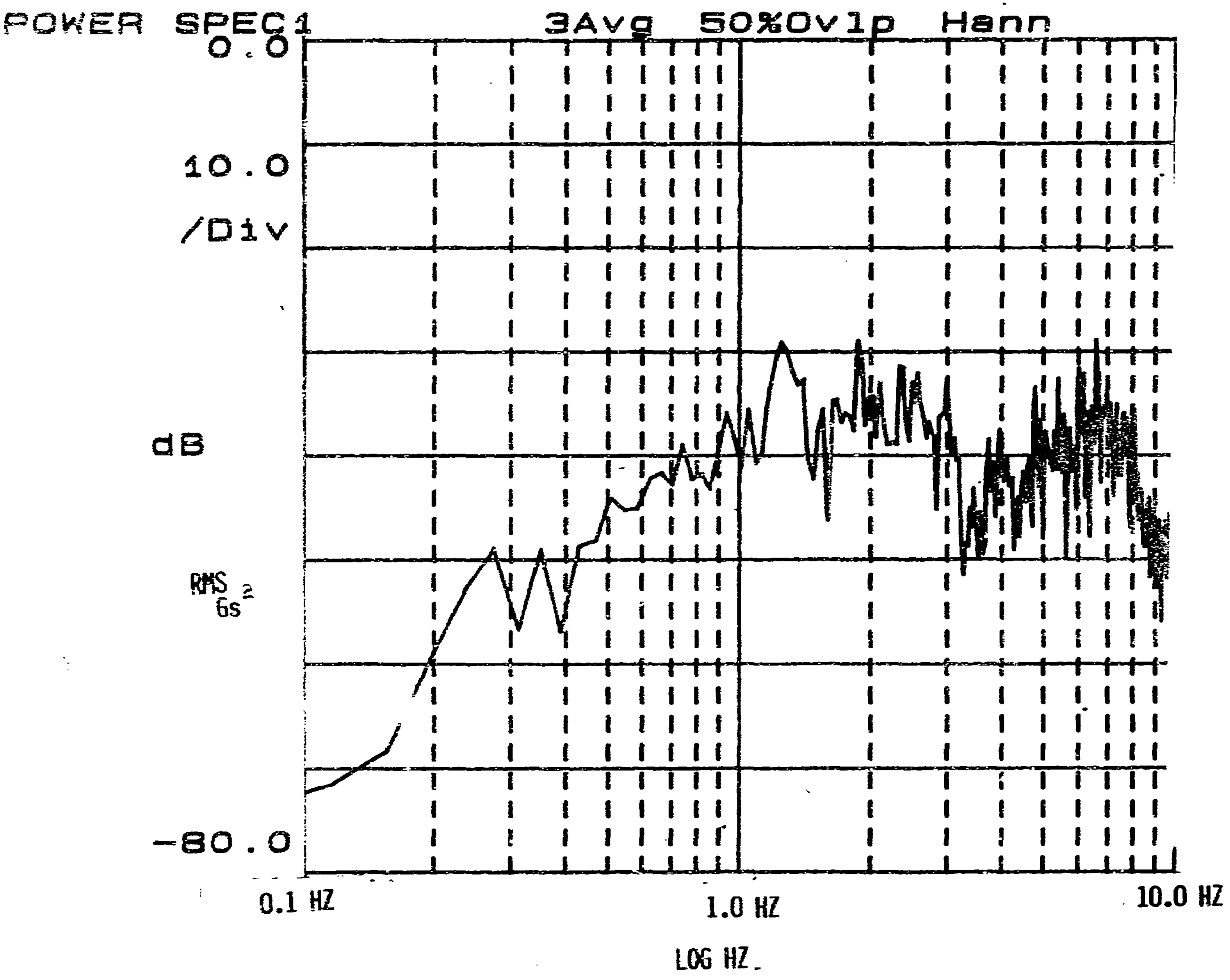
MEASURED POWER SPECTRAL ANALYSIS
VERTICAL SEAT ACCELERATION

9.8 MPH APG11

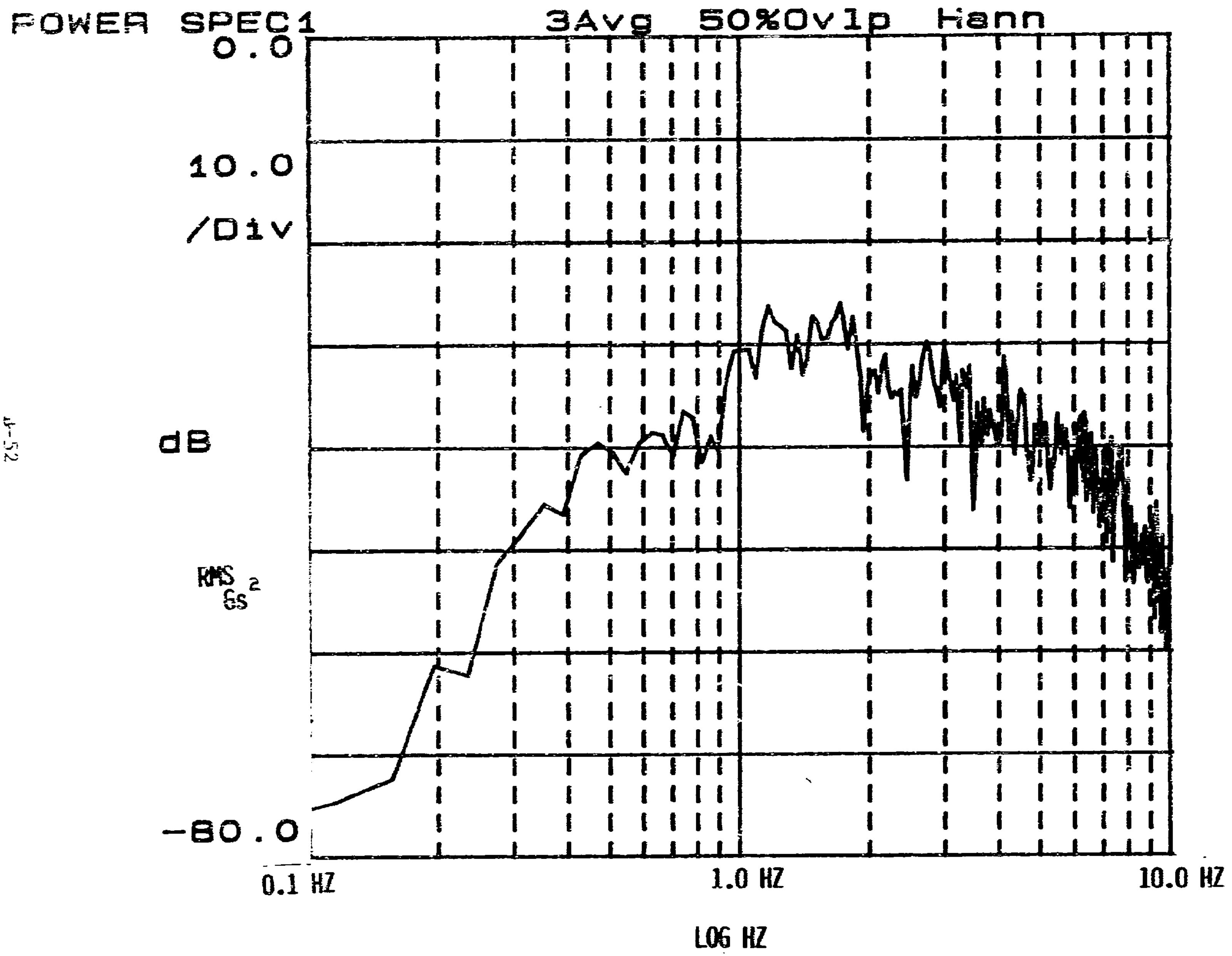


MEASURED POWER SPECTRAL ANALYSIS
VERTICAL SEAT ACCELERATION

10 MPH APG12

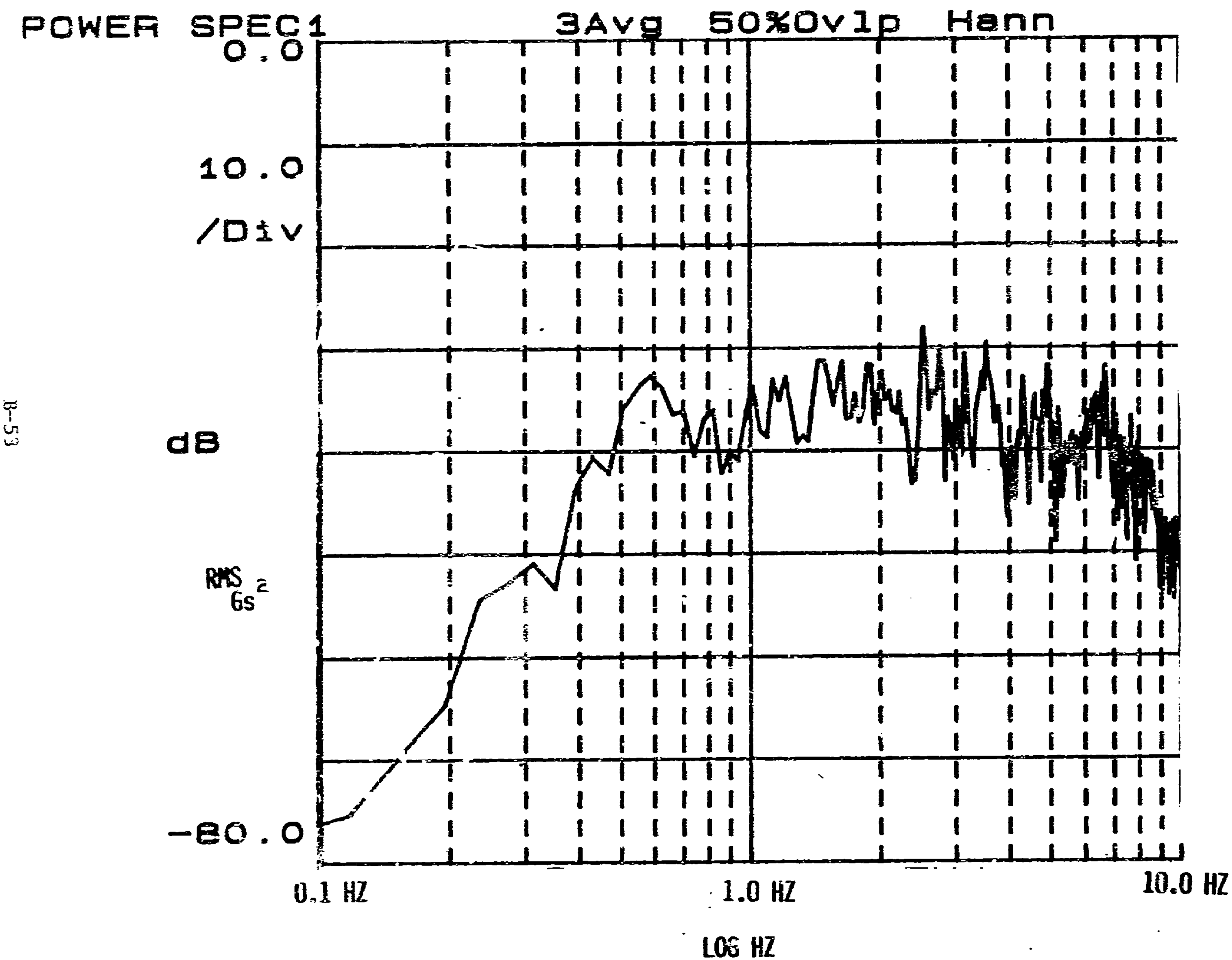


MEASURED POWER SPECTRAL ANALYSIS 8.5 MPH AP629
VERTICAL SEAT ACCELERATION



MEASURED POWER SPECTRAL ANALYSIS
VERTICAL SEAT ACCELERATION

12 MPH FORT KNOX 910



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